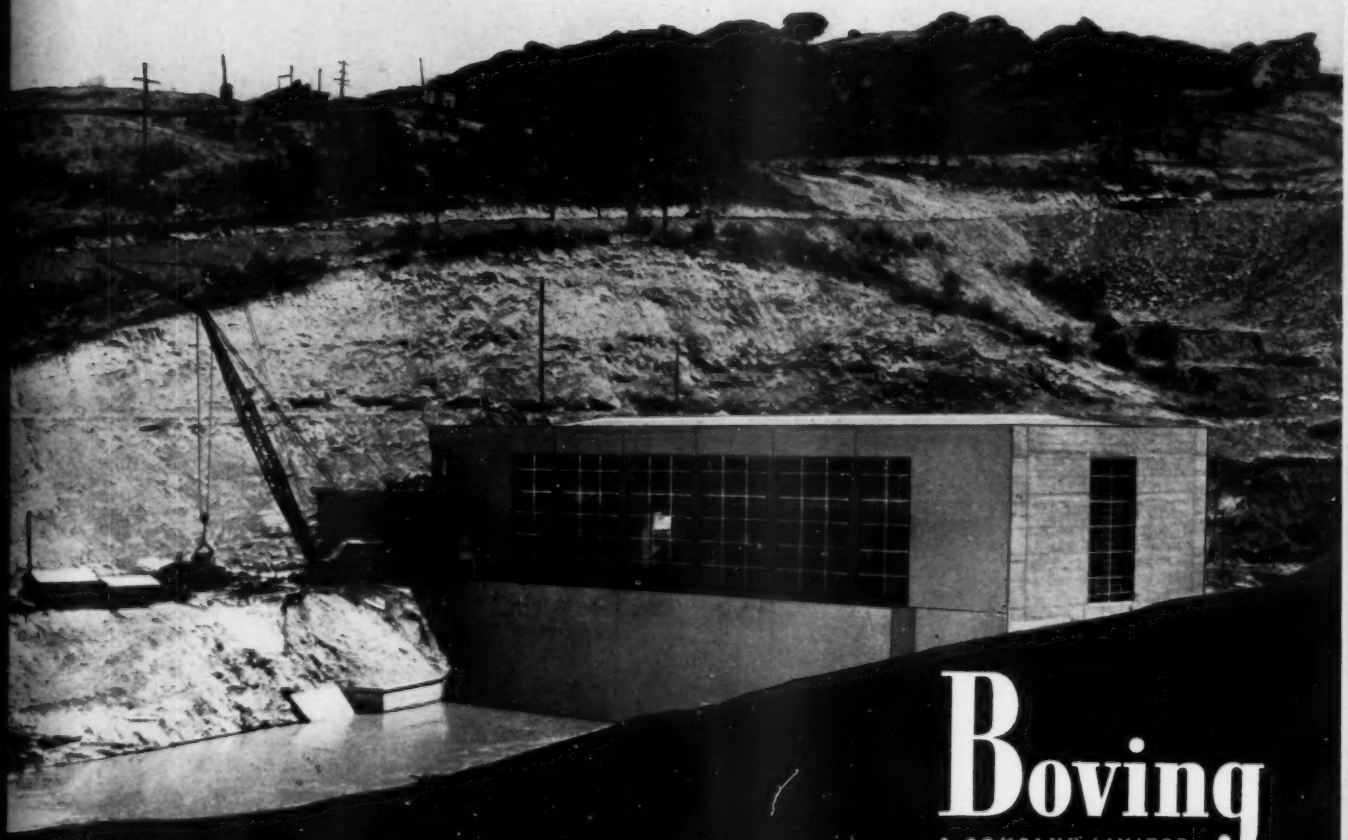
Water Power
INTERNATIONAL JOURNAL OF HYDRO-ELECTRIC POWER
MAY 1958

TECHNOLOGICAL
MAY 20 1958

Eildon Power Station

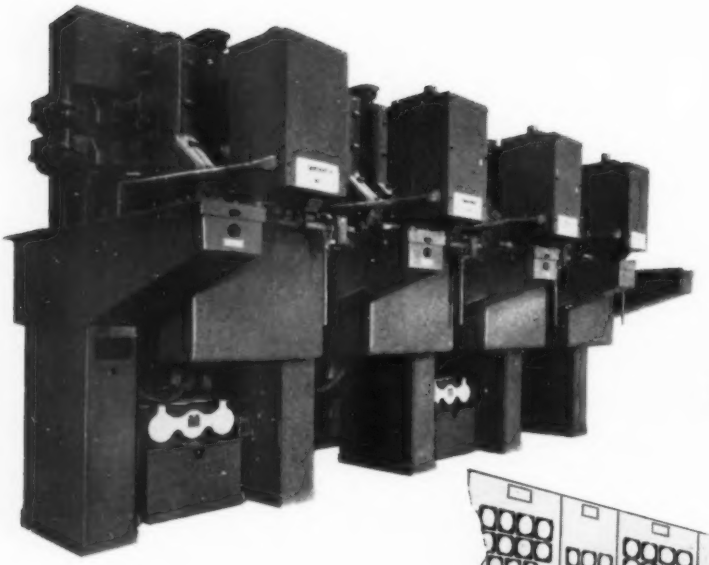
On the 21st January 1957 the first unit was placed on full load — 60 MW — the largest water turbine to be commissioned in Australia. The Station contains 2-82, 100 H.P. Boving Francis turbines coupled to B.T.H. 60 MW generators. Head 230 ft. Speed 150 r.p.m.



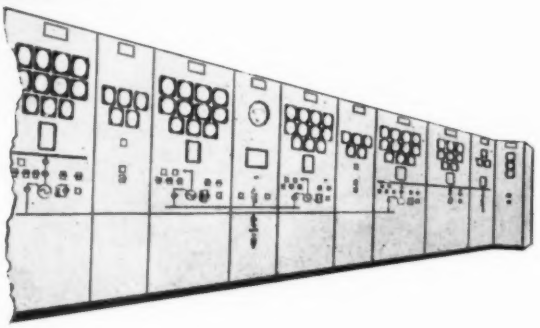
Boving
& COMPANY LIMITED

WATER POWER ENGINEERS

LONDON · AUSTRALIA · NEW ZEALAND · INDIA · PAKISTAN



generator switchgear at Calder Hall

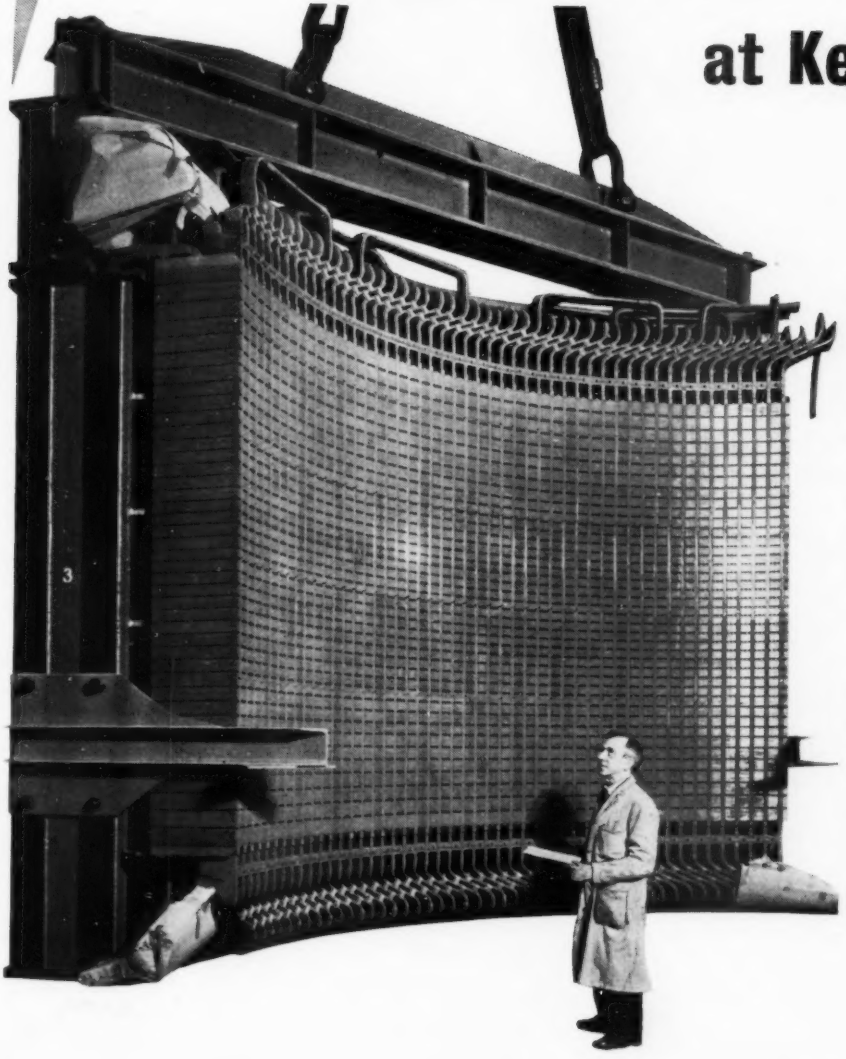


The generators at the
Calder Hall Power-station
of the Atomic Energy Authority
are controlled by Reyrolle
11-kV 500-MVA and
750-MVA switchboards
and their associated
control-boards

Reyrolle

A. REYROLLE & COMPANY LIMITED HEBBURN, COUNTY DURHAM, ENGLAND

MORE POWER
at Kemano



A repeat order for an alternator for the Kitimat project of the Aluminum Company of Canada has recently been completed. This machine is rated at 114,000 kVA with an overload rating of 132,000 kVA.

The photograph shows a section of the stator of the second machine ready for packing in the works.

'ENGLISH ELECTRIC'
hydro-electric equipment

THE ENGLISH ELECTRIC COMPANY LIMITED, MARCONI HOUSE, STRAND, LONDON, W.C.2

Hydro-electric Department, Netherton, Bootle, 10

HE.20C8 WORKS: STAFFORD · PRESTON · RUGBY · BRADFORD · LIVERPOOL · ACCRINGTON

VOITH

HEIDENHEIM/GERMANY

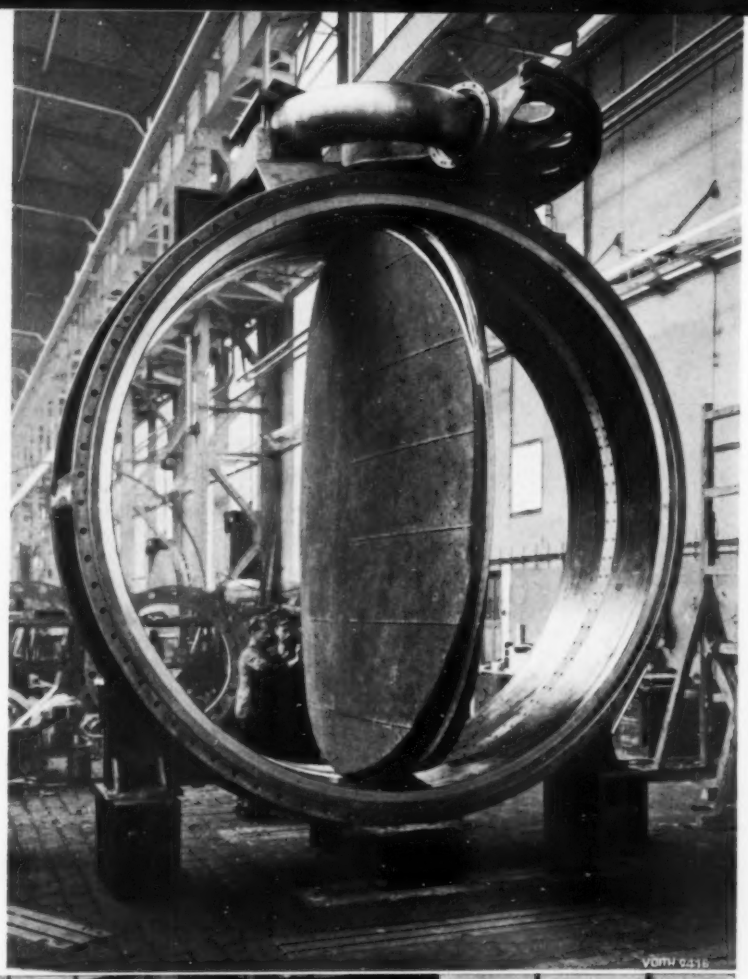
For the successful and dependable operation of hydro-electric power plants

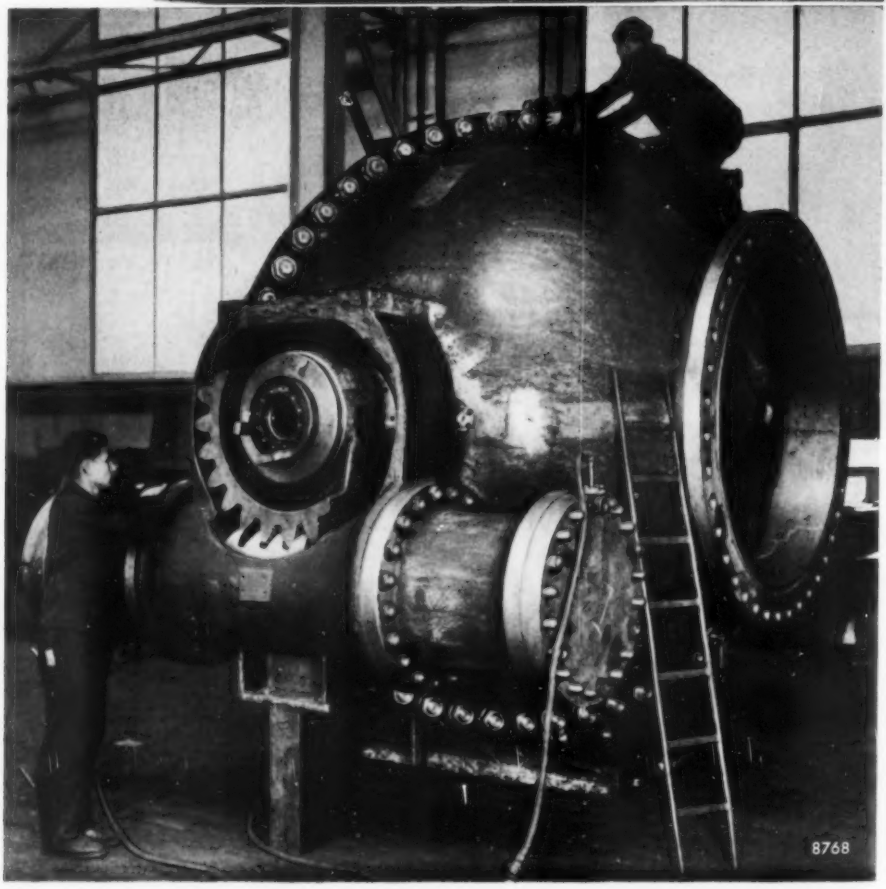
SHUT-OFF VALVES

are no less essential than water turbines

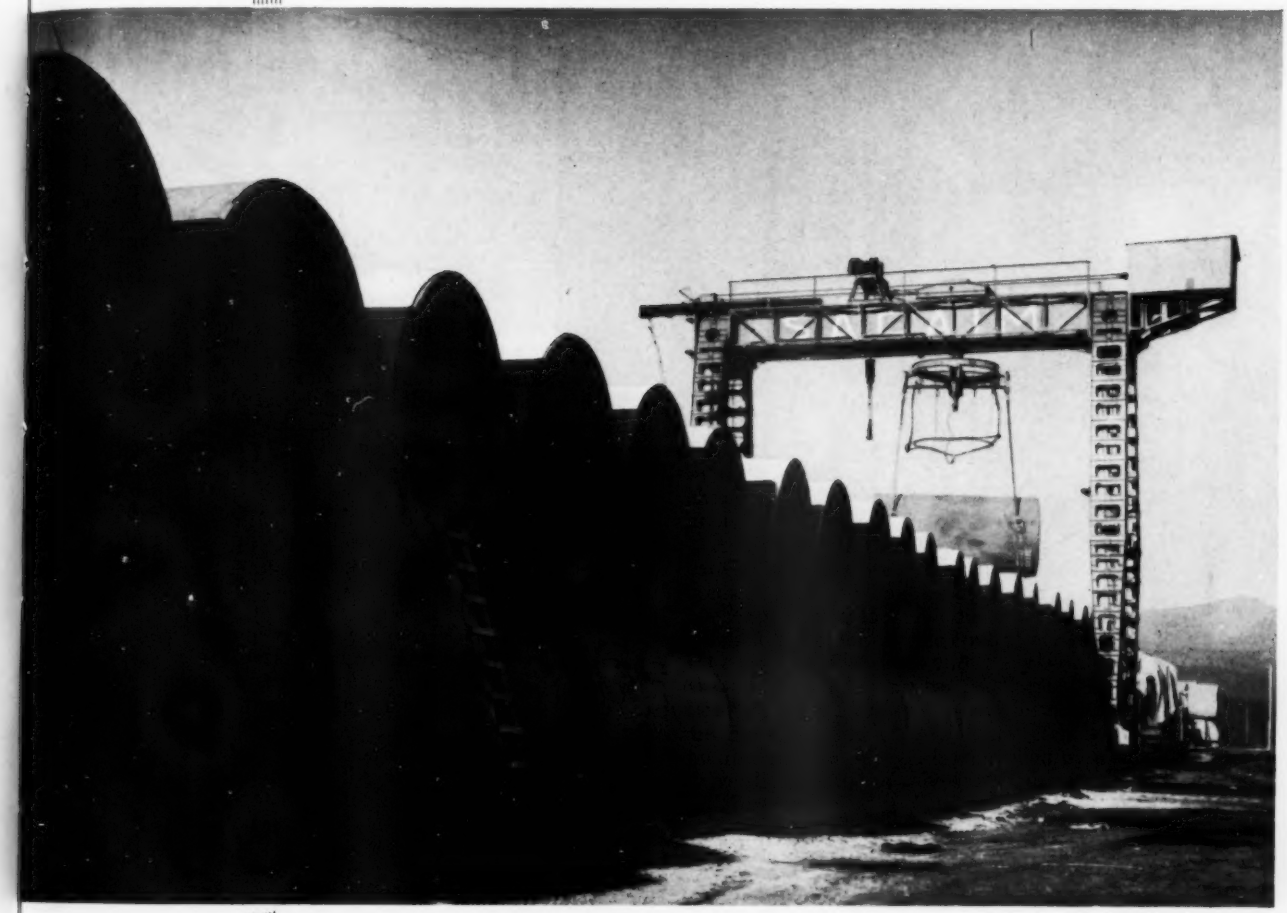
(top) One of three 12ft. 6in. dia. all-welded weight-actuated butterfly valves for installation at the beginning of the penstocks of the Geesthacht Pumped Storage Plant near Hamburg, which is equipped with another three Voith butterfly valves of the same physical size to shut off the water flow to the turbines.

(bottom) 5ft. 6in. dia. Voith rotary valve as used ahead of the turbines in the Reisach-Rabenleite Pumped Storage Plant (Bavaria).





Prestressed reinforced concrete penstocks of any diameter and pressure



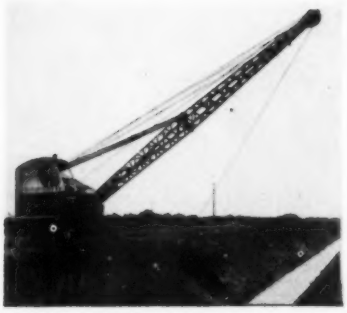
Main penstock of prestressed reinforced concrete (diameter 6 ft. 7 ins., operating at 440 lb. per sq. in.) made for the Maè - Piave Hydro-Electric station of
S.A.D.E. - SOC. ADRIATICA DI ELETTRICITA'

SACAIM

Soc. p. Az. Cementi Armati Ing. Mantelli

VENICE (ITALY) - Accademia 979/A - Telephone 24.072

22-RB transit crane with 80' boom operating with out-riggers set
TARSLAG LIMITED of ROTHERHAM now include two of these machines in their hire fleet



10-RB ¾ cu.yd. dragline dyke-cleaning in the Fens

30-RB 1 cu. yd. shovel loading rock in a road stone quarry

Discrimination and Excavation

Under present economic circumstances, more than ever before, the contractor needs to discriminate before he decides to purchase equipment vital to his needs.

Consideration of the Ruston-Bucyrus range of excavators, particularly in the universal group of ⅜ to 1 cubic yards capacity, will suggest a ready solution to your excavating problems. The four machines in this category : **10-RB ⅜ cu. yd., 19-RB ½ cu. yd., 22-RB ¾ cu. yd.** and the new **30-RB 1 cu. yd.** with air control, are ready and waiting to be applied to that new contract where their ability to do *more work* quicker and *at less cost* will increase your profit margin.

Write now for information on the size of machine in which you are interested

19-RB ½ cu.yd. dragshove excavating pipe trenches for a water supply

RUSTON–BUCYRUS

RUSTON-BUCYRUS LIMITED, EXCAVATOR SPECIALISTS, LINCOLN

THE COMPLETE RANGE OF RUSTON-BUCYRUS EXCAVATORS IS FROM ⅜ TO 6 CUBIC YARDS CAPACITY

ESCHER WYSS STORAGE PUMPS

Some recent deliveries:

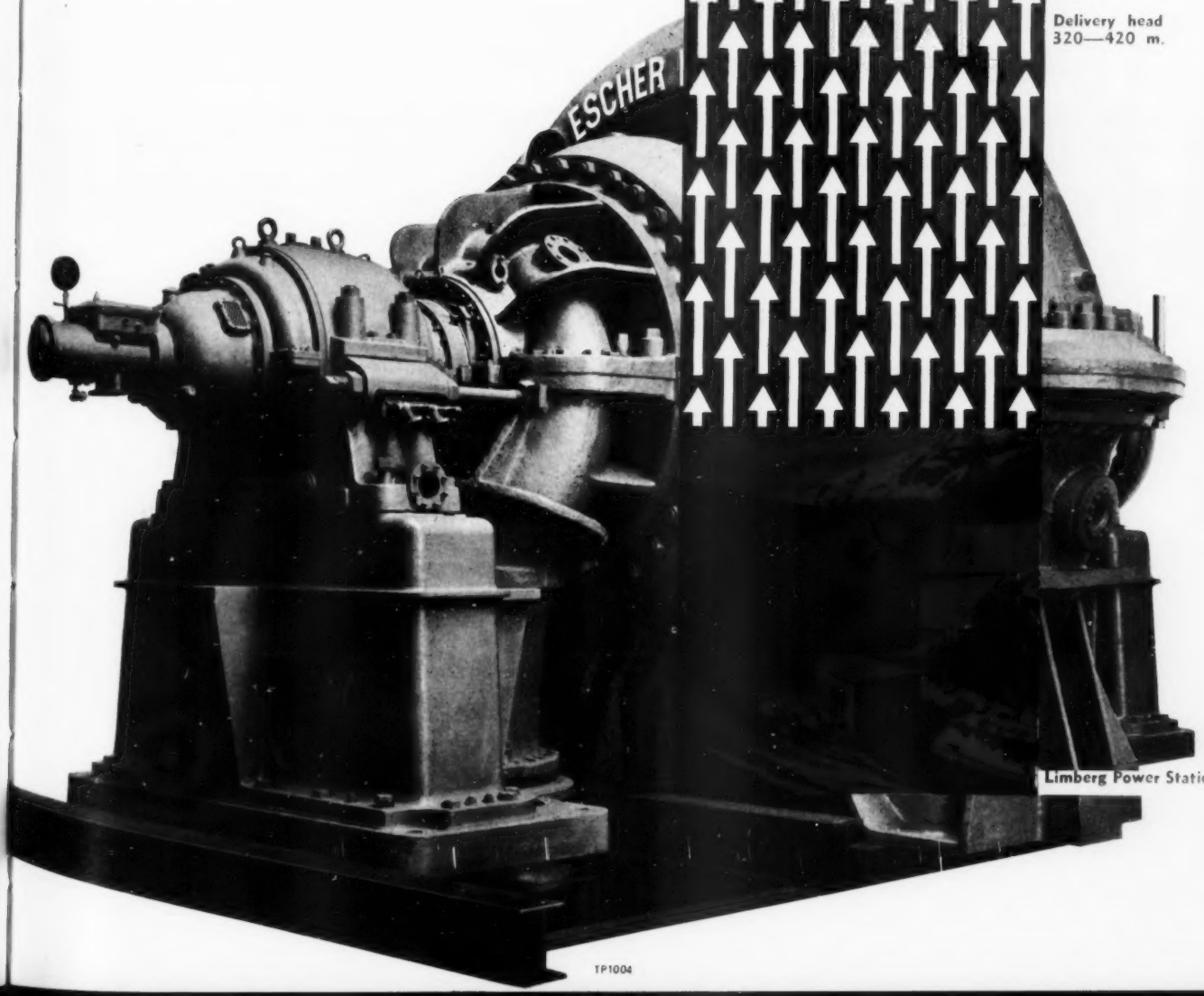
Häusern (Schluchsee)	2 pumps of	32 600 HP
Cotilia-Turano	2 pumps of	37 600 HP
Witznau (Schluchsee)	2 pumps of	40 000 HP
Hamburg	3 pumps of	43 600 HP
Lünersee	2 pumps of	57 600 HP
Provvidenza	2 pumps of	62 700 HP
Limberg	2 pumps of	**85 000** HP

ESCHER WYSS LTD ZURICH

(SWITZERLAND)

Storage lakes of Mooserboden and Wasserfallboden

Delivery head 320—420 m.



Limberg Power Station

TP1004

A. G. SS. MM. VERONA

SPECCHERI DAM ON THE LENO RIVER

HEIGHT 525½ ft · CREST LENGTH 515 ft · CONCRETE VOLUME 160,000 cu. yds

DOTT. ING. G. TORNO & C. SOC. P. AZ.

BUILDING & CIVIL ENGINEERING CONTRACTORS & CONSULTANTS

7, VIA GEN. ALBRICCI · **MILANO (ITALY)** · CABLE ADDRESS: **IDROTORNO**

SOCIETE DES FORGES ET ATELIERS DU CREUSOT (USINES SCHNEIDER)
15, Rue Pasquier, PARIS 8e - Tél. : Anjou 34-40

LE MATÉRIEL ÉLECTRIQUE S-W
Constructions électriques SCHNEIDER
Licence WESTINGHOUSE
32, Cours Albert-1er PARIS 8e Tel. : BAL. 57-50

COMPAGNIE INDUSTRIELLE DE TRAVAUX (ENTREPRISES SCHNEIDER)
16, Boul. Malesherbes, PARIS 8e - Tél. : Anjou 34-40

Laksapana Power Plant (Ceylon) : Penstocks

Serre-Ponçon Dam Project : concrete gallery extending over 7,000 ft.

Laksapana Power Plant : Two 16,100 kW Pelton units under erection

CONSTRUCTION AND ERECTION OF ANY HYDRAULIC POWER PLANT EQUIPMENT

Penstocks, Valves, Turbines, Alternators, Electric Switchgear, Transformers, etc...

CIVIL ENGINEERING WORK

A. O. SMITH MULTI-LAYER PENSTOCKS

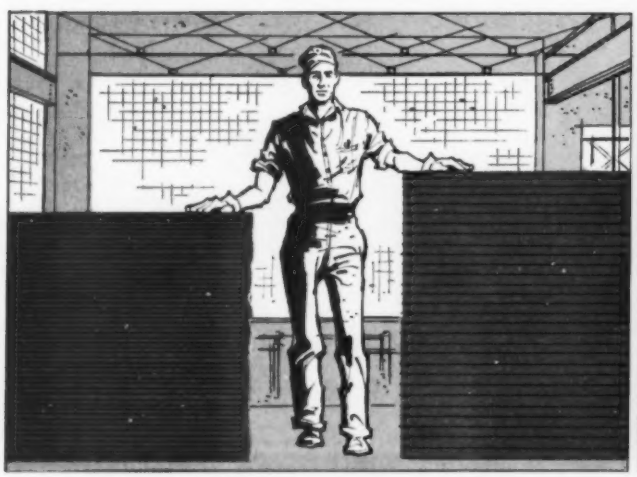
How built-up walls cut down costs

Savings start—then grow, the moment A. O. Smith MULTI-LAYER penstocks are installed. Ideally suited for high hydrostatic pressures, MULTI-LAYER's remarkable strength results from the *number* and *type* of built-up thin steel plates required to handle your job.

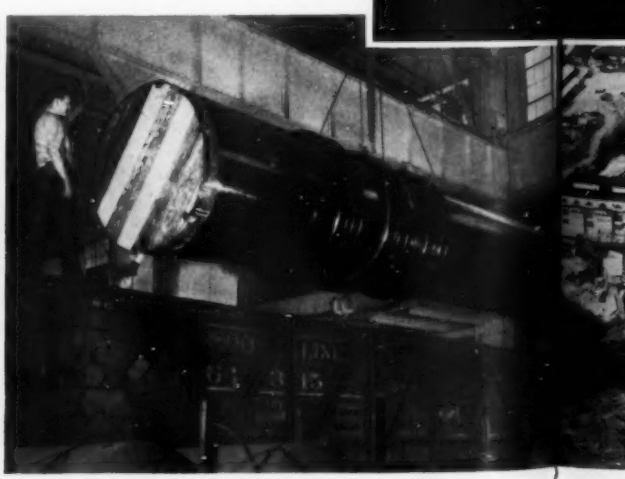
Critical material control such as this offers optimum safety and strength at lowest possible cost. Yet there's no practical limitation to the pressures that can be handled.

A complete selection of MULTI-LAYER sizes are available . . . small-diameter, thin-wall up to 30″ . . . larger diameters made to order including "wyes," "bends," and other "specials."

For aid in solving penstock problems, backed by unlimited research and production facilities, write A. O. Smith International S. A., Administrative Offices: P. O. Box 331, Milwaukee 1, Wis., U. S. A.



MULTI-LAYER saves up to 15% in amount of steel required for conventional *thick* plate, single wall penstocks of the same diameter. MULTI-LAYER *saves tonnage.* Layers of thin, high-tensile strength steel plate are progressively wrapped, tightened and welded around the core.



MULTI-LAYER saves in freight and cargo costs. A. O. Smith MULTI-LAYER penstocks weigh less . . . shipping costs are substantially cut. Especially important when jobs are located in remote areas. Handling and erection are faster, easier at the job site.

Manufacture of MULTI-LAYER pipe section. This modern A. O. Smith construction results in lighter, safer and more easily welded high-head penstock sections, as compared to ordinary single wall construction.

MULTI-LAYER saves by eliminating costly stress-relieving of welds in the field. Residual stresses in welds are negligible. MULTI-LAYER requires no bothersome, time-consuming handling of sections into and out of stress-relieving furnaces.

Through research A.O. Smith *... a better way*

A.O.Smith

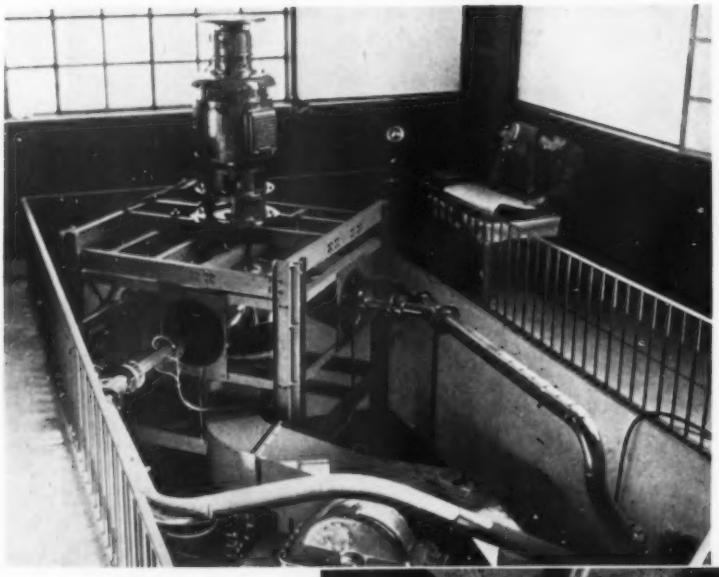
INTERNATIONAL S. A.

Administrative Offices:
P. O. Box 331,
Milwaukee 1, Wisconsin, U.S.A.

FRANCO TOSI S.p.a ★ LEGNANO (ITALY)

HYDRAULIC TURBINES

KAPLAN ★ FRANCIS ★ PELTON ★ GOVERNORS ★ VALVES



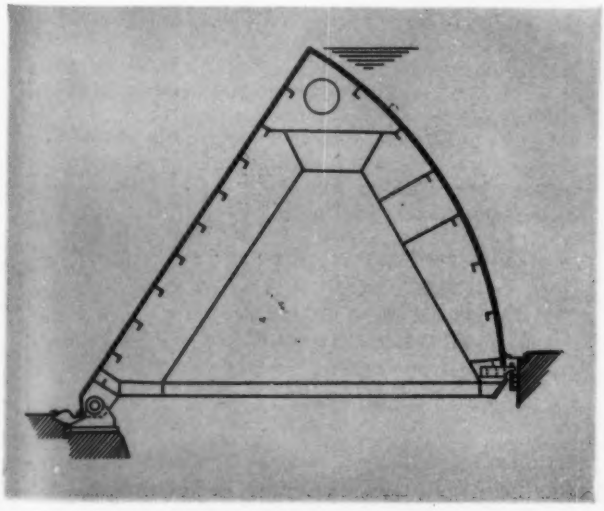
Franco Tosi testing facilities on scale model turbines installed in A.F.L. Falck Hydroelectric Station of Teglia (Tuscany district Apennine, Northern Italy).

Above and at right:
Vertical, 4 nozzle Pelton type model turbine, with transparent plexiglass casing, being tested.

Three Kaplan runners of different specific speeds which have been tested

M·A·N

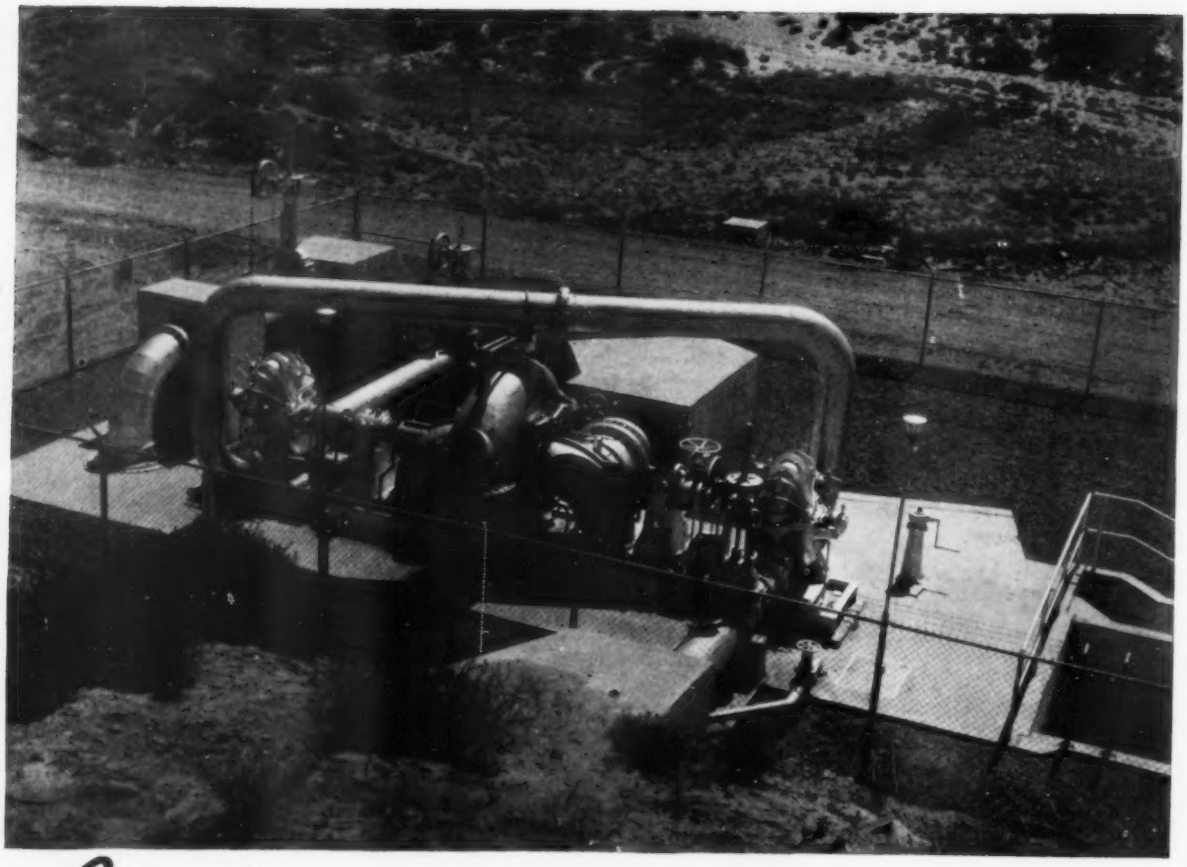
1001/58



HYDRAULIC STRUCTURES

Sector weir of 50 m clear width and 4.55 m water head in the River Elbe at Geesthacht near Hamburg. Illustration shows the gate in course of erection. Sector weirs are hydraulically operated submersible gates moved by regulation of the water enclosed in the sector chamber. As opposed to drum gates, they are particularly appropriate for weir plants in rivers where comparatively slight variation in the water level occurs.

MASCHINENFABRIK AUGSBURG-NÜRNBERG AG · GUSTAVSBURG WORKS
GUSTAVSBURG/HESSEN (GERMANY) · REPRESENTATIVES IN ALL COUNTRIES



Another LEFFEL TURBINE FOR KENNEWICK

Now, there are Leffel hydraulic turbines at work in two Kennewick Division stations . . . the recently completed Amon Pumping Plant and the Chandler Power and Pumping Plant. Located in the southeastern section of the State of Washington, the Kennewick Division of the Yakima Project is being developed by the Bureau of Reclamation of the U.S. Department of the Interior.

The Amon Pumping Plant, unusual because of its outdoor installation, is powered by a Leffel turbine which withstands the effects of wind and sand, in addition to performing at top turbine efficiency. This turbine is the horizontal shaft discharge spiral case type, and is rated to develop 700 H.P. under 63 ft. net head, speed 600 R.P.M. Directly connected at each end to a centrifugal pump, the turbine unit has a discharge elbow coming off either side. This turbine, like larger Leffel turbines throughout the world, harnesses water power efficiently and economically.

Leffel has the technical knowledge and wide range of experience necessary to design and build hydraulic turbines for most any size installation.

Leffel can help you with your project, big or small, whether it be expansion, rehabilitation, or a new installation. Mail the coupon below TODAY for complete details. There's no obligation. 1101-E

THE JAMES LEFFEL & CO.

FOUNDED IN 1862

MORE EFFICIENT HYDRAULIC POWER FOR 96 YEARS

FREE LITERATURE

THE JAMES LEFFEL & COMPANY

Dept. W, SPRINGFIELD, OHIO, U.S.A.

☐ Please send me more information on Leffel hydraulic turbines.

☐ Please have your representative call.

Name_____ Title_____

Company_____

Address_____

40 miles of tunnelling

New high speed tunnelling techniques have been employed with outstanding success on contracts executed by The Mitchell Construction Company for the North of Scotland Hydro-Electric Board. The illustration shows the junction of the Doe and Ceannacroc Tunnels on the Glenmoriston Scheme, whilst the inset shows the access tunnel to Ceannacroc Underground Generating Station. Included in the Company's contracts with the Board is nearly 40 miles of hard rock tunnelling, of which 27 miles has already been driven.

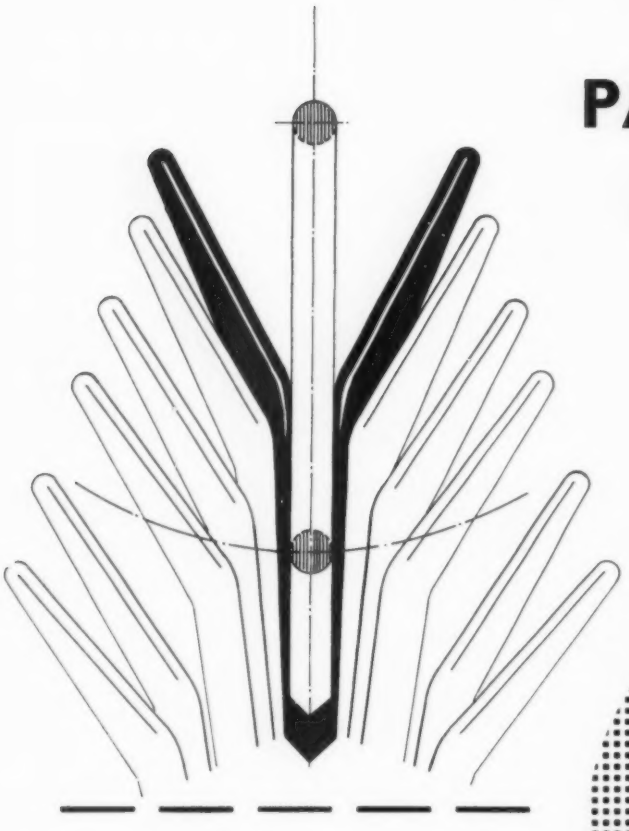
CONSULTING ENGINEERS
SIR WILLIAM HALCROW & PARTNERS

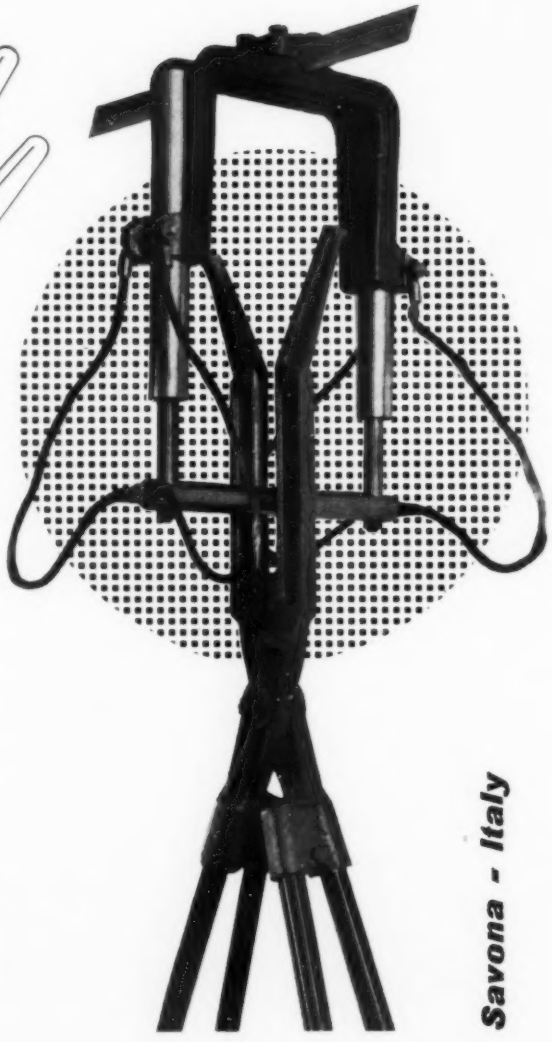
THE MITCHELL CONSTRUCTION COMPANY

WHARF WORKS PETERBOROUGH

MITCHELL

PANTOGRAPH ISOLATORS



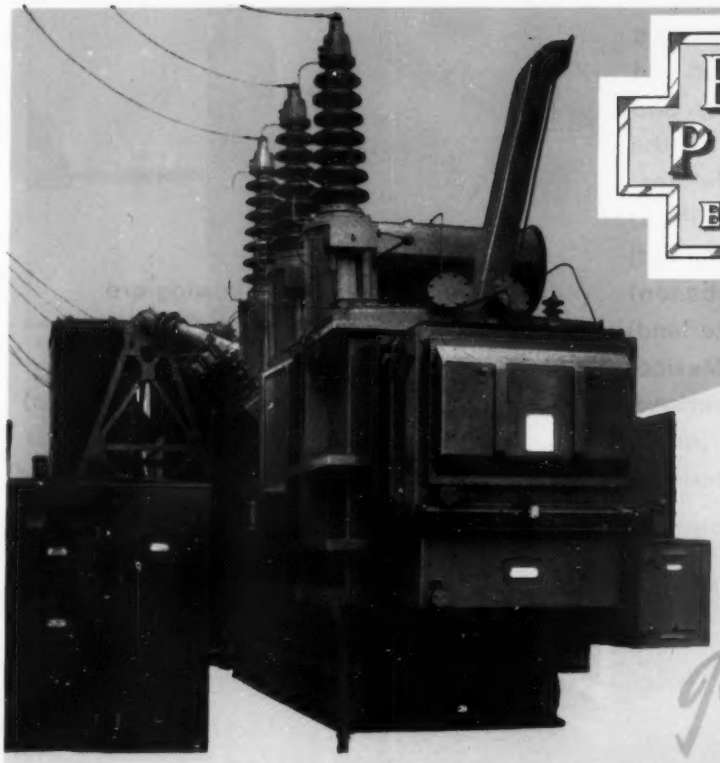


SCARPA & MAGNANO pantograph isolators are fitted with a special flexible bridle, suspended from the line conductor, which compensates automatically for transverse oscillations and also for vertical movements induced by changes of temperature. Owing to the compensating action of this bridle and to the long gripping surfaces of the pincer-type moving contacts, SCARPA & MAGNANO pantograph isolators can be employed with complete safety even in the middle of a long conductor span.

When an isolator is closed, the pressure of the special bridle and the high degree of flexibility of the pantograph linkwork enable the isolator to adapt itself to line oscillations over a wide range without subjecting the insulator parts to excessive stresses.

Savona - Italy

SCARPA & MAGNANO



BRUCE PEEBLES
EDINBURGH

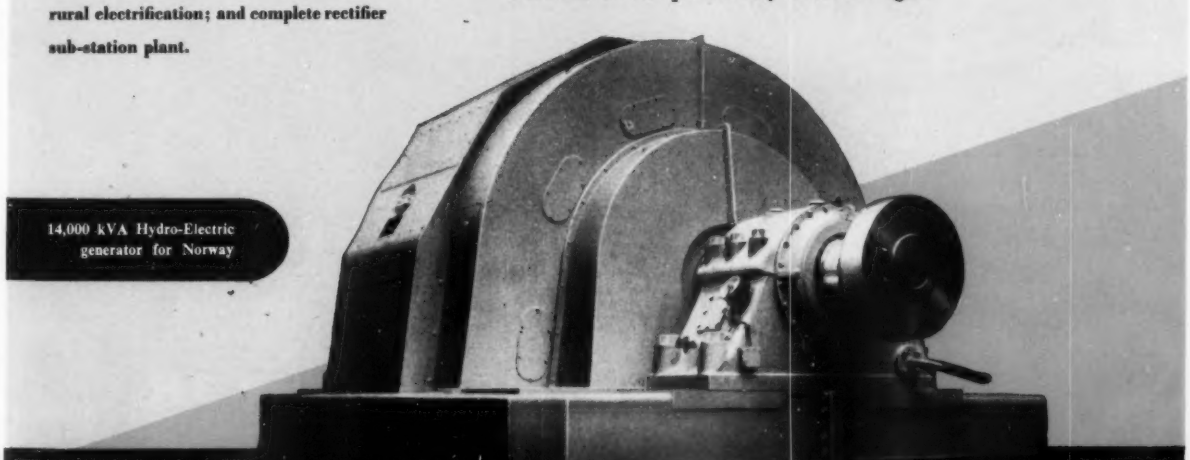
45 MVA 132/33 kV transformer for the Central Electricity Authority

Pioneers

OF THE ELECTRICAL INDUSTRY WITH OVER 50 YEARS' MANUFACTURING EXPERIENCE.

Activities embrace a wide variety of manufacture ranging from heavy rotating plant for the generation and conversion of electrical energy to motors for every sphere of industry: transformers of well over 100 MVA for 275 kV service to the smallest unit for distribution schemes and rural electrification; and complete rectifier sub-station plant.

For generations the name of Bruce Peebles has been famous for the manufacture of electrical power plant. Throughout its whole history the Company has ever been progressive, and its pioneering work has played an important role in the evolution of the present-day electrical age.

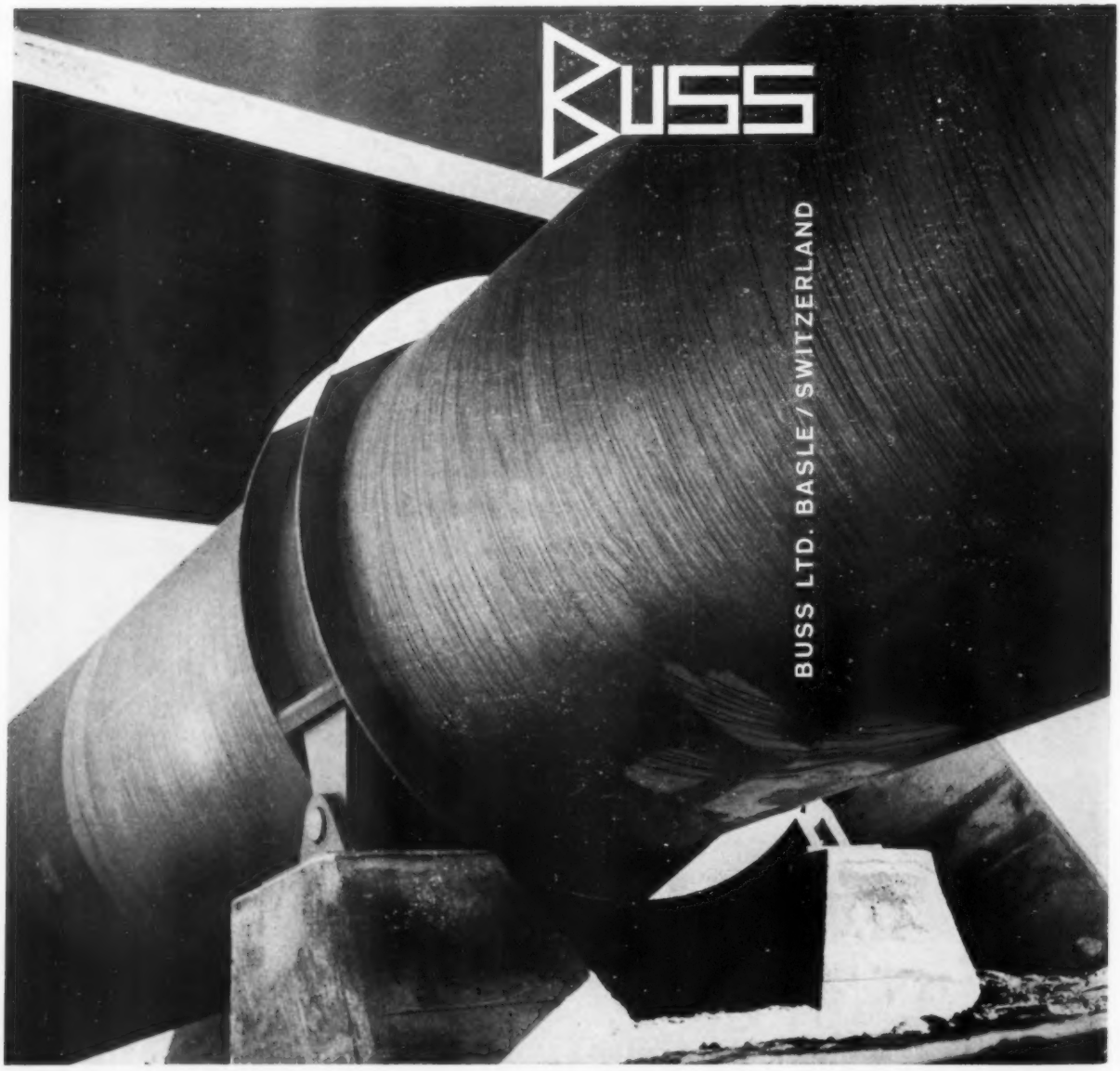


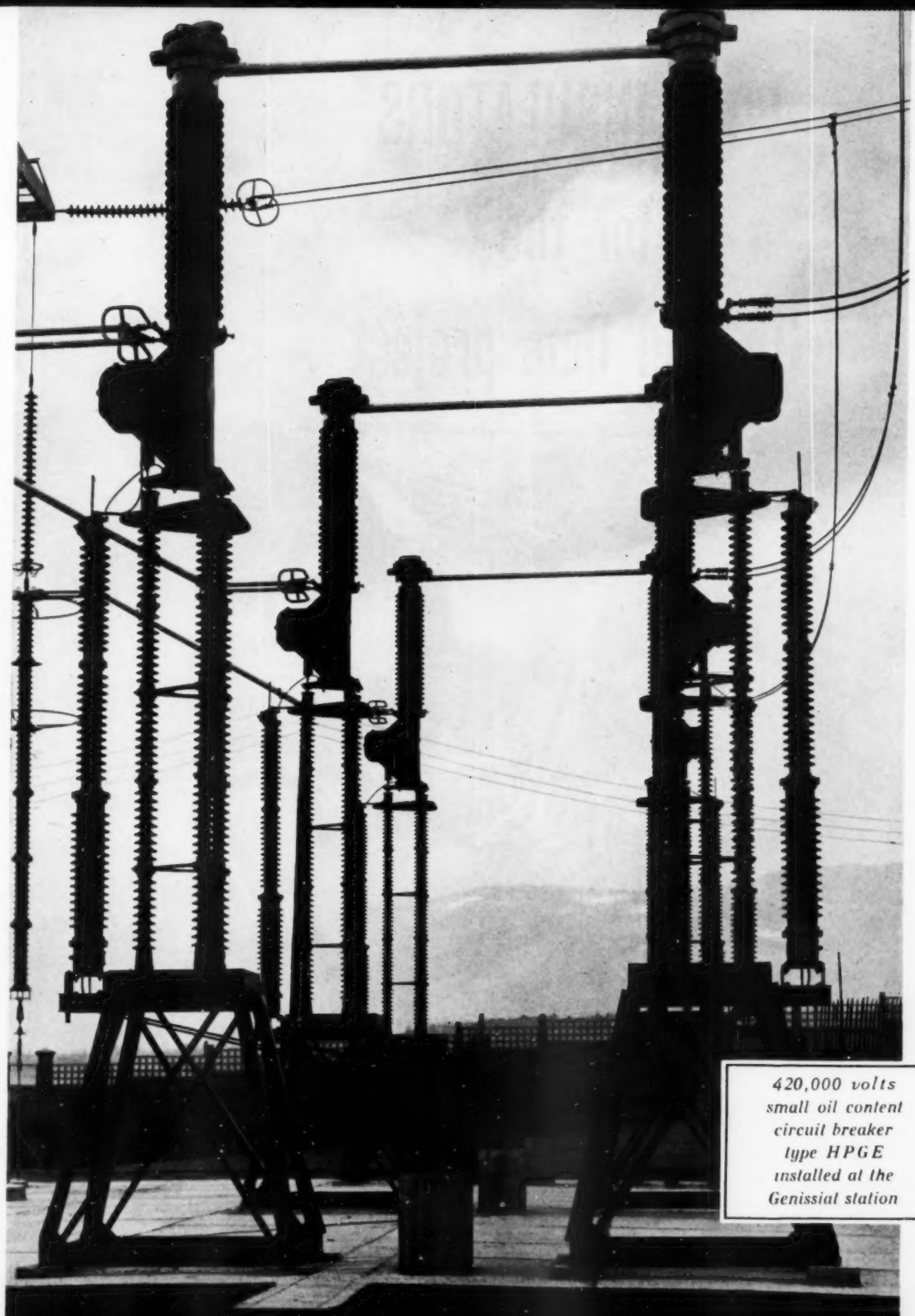
14,000 kVA Hydro-Electric generator for Norway

BRUCE PEEBLES & CO. LTD. EDINBURGH. SCOTLAND

In the past few years
we have manufactured and
erected pipe-lines and
tunnel reinforcements for the
following hydraulic schemes:
Moyopampa (Peru)
Calancasca (Switzerland)
Kaftoun (Lybanon)
Châtelot (Switzerland)
Patla (Mexico)
Cavergno (Maggia, Switzerland)
Zongo (Belgian Congo)
Safien (Switzerland)

The following are
still in execution:
Vissoie (Switzerland)
Kiymbi (Belgian Congo)
Pontirone (Switzerland)
Göschenen (Switzerland)





420,000 volts small oil content circuit breaker type HPGE installed at the Genissiat station

THE WHOLE OF APPARATUS UP TO 500,000 VOLTS

Ateliers de Constructions Electriques de

DELLE

DE LA COMPAGNIE GÉNÉRALE D'ELECTRICITÉ
25, CHEMIN DE CYPRIAN - VILLEURBANNE - FRANCE

9943

POST INSULATORS for the Hirakud Dam project

S.P.P. Post Insulators were supplied for the 132kV. outdoor switchgear on the Hirakud Dam Project.

S.P.P. Post insulators have also been used on all the major hydro-electric projects in India, including the following:—

Damodar Valley Corporation
U.P. Government
Madras Government
Mysore Government
Travancore—
Cochin Government
Bombay Grid Scheme
Jog Falls Scheme
Machkund Scheme
North Calcutta Scheme
Pallivasal Scheme
Tungabhadra Scheme
Kunda, Madura, Mettur Dam, Moyar, Papanasam and many other substations on the Madras Grid.

STEATITE & PORCELAIN PRODUCTS LTD.

Stourport-on-Severn, Worcestershire. Telephone : Stourport 2271. Telegrams : Steatain, Stourport

SP94A

VeVeY

Complete

equipment for Hydro-electric Power Plants

Turbines

governors

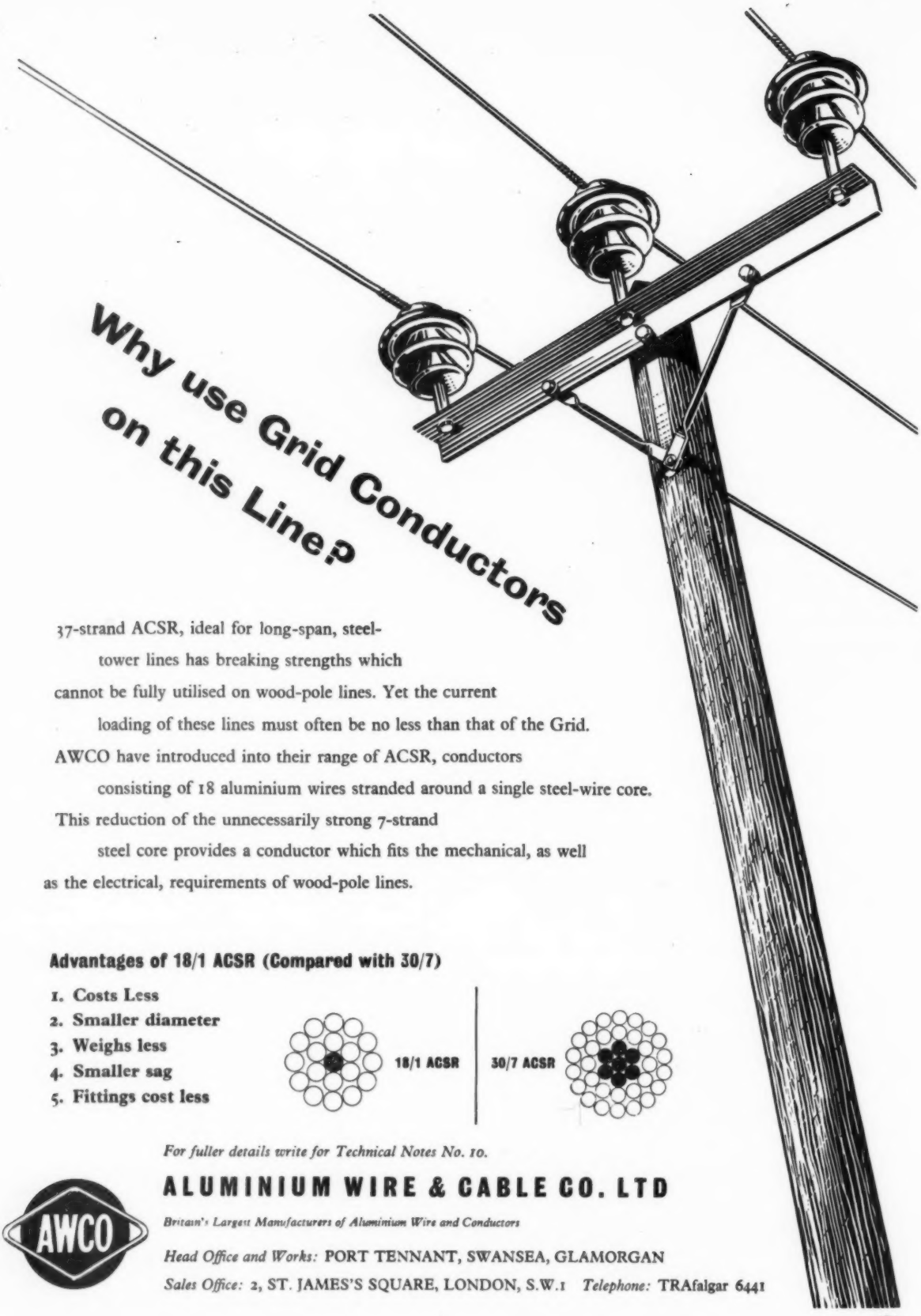
penstocks

valves

travelling cranes

Ateliers de Constructions Mécaniques de Vevey S.A.

1471 E



Why use Grid Conductors on this Line?

37-strand ACSR, ideal for long-span, steel-tower lines has breaking strengths which cannot be fully utilised on wood-pole lines. Yet the current loading of these lines must often be no less than that of the Grid. AWCO have introduced into their range of ACSR, conductors consisting of 18 aluminium wires stranded around a single steel-wire core. This reduction of the unnecessarily strong 7-strand steel core provides a conductor which fits the mechanical, as well as the electrical, requirements of wood-pole lines.

Advantages of 18/1 ACSR (Compared with 30/7)

1. **Costs Less**
2. **Smaller diameter**
3. **Weighs less**
4. **Smaller sag**
5. **Fittings cost less**

18/1 ACSR

30/7 ACSR

For fuller details write for Technical Notes No. 10.

AWCO

ALUMINIUM WIRE & CABLE CO. LTD

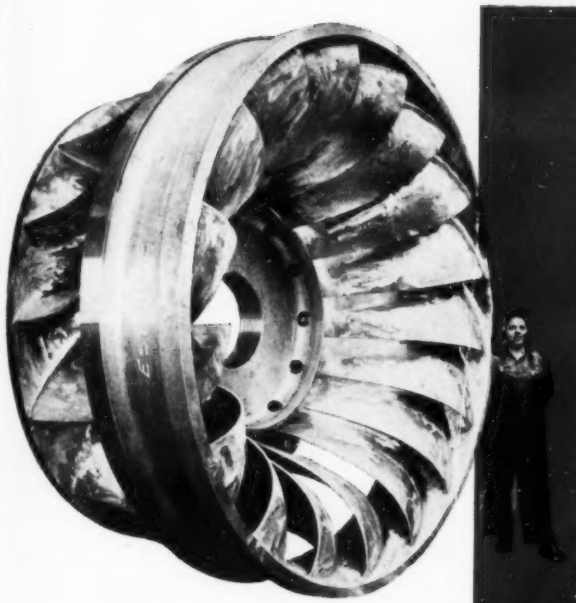
Britain's Largest Manufacturers of Aluminium Wire and Conductors

Head Office and Works: PORT TENNANT, SWANSEA, GLAMORGAN

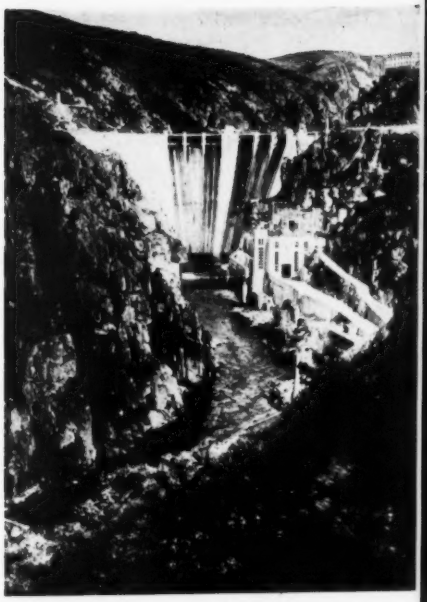
Sales Office: 2, ST. JAMES'S SQUARE, LONDON, S.W.1 *Telephone:* TRAfalgar 6441

AP44

More than 20 million KMW horsepower in 50 countries



90,700 h.p. runner for one of the four KMW Francis turbines for San Esteban.



The Spanish power station of San Esteban belonging :o the Saltos del Sil S.A., where the fourth KMW unit has recently been put into service.

KMW started manufacture of water turbines in 1880 and had up to the beginning of 1958 received orders for 2,765 units with a total output of 12·4 million horsepower, of which 4·7 million horsepower are Kaplan turbines. If the KMW turbines built by our licensees are included, these totals can be increased to 20 and 7 million horsepower respectively. These figures show that KMW turbines are in great demand for power stations all over the world.

Among the turbines recently delivered or ordered can be mentioned:

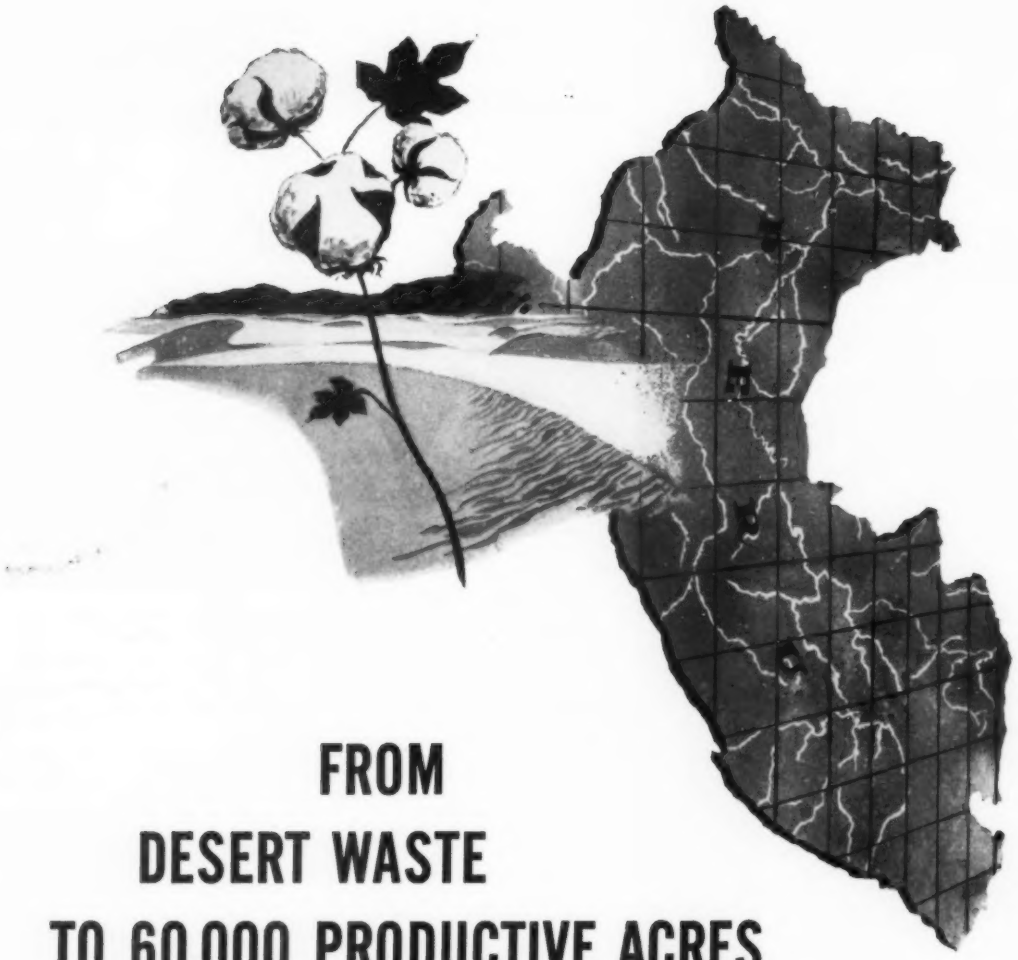
Number of units	Type	Client	Plant	Country	Total output h.p.	Net head feet	r.p.m.
2	Kaplan	Bålforsens Kraft AB	Bålforsen	Sweden	102,220	102	150
2	Pelton	Hjartdöla Kraftverk	Hjartdöla	Norway	142,000	1,820	428
1	Francis	A. Johnson & Co. (Canada) Ltd.	Willson	Canada	82,000	263	180
2	Kaplan	Swedish State Power Board	Järkvissle	Sweden	118,920	45	75
3	Kaplan	Bjurfors AB	Bjurfors	Sweden	101,550	64	125
3	Francis	Empresa Nacional de Electricidad S.A.	Pullinque	Chile	67,200	156	250
2	Francis	Stora Kopparbergs Bergslags AB	Trängslet	Sweden	280,000	459	214
2	Kaplan	Graningeverkens AB	Kvistforsen	Sweden	183,000	164	150
2	Francis	Stockholms Superfosfatfabriks AB	Parteboda	Sweden	42,700	105	167
2	Francis	AB Mölnbacka—Trysil—Höljes Kraftverk	Höljes	Sweden	182,800	284	187·5

AB KARLSTADS MEKANISKA VERKSTAD

KARLSTAD — SWEDEN

Representatives in Canada: A. Johnson & Co. (Canada) Ltd.,
607 Shell Tower Building, Montreal 2.

KMW



FROM DESERT WASTE TO 60,000 PRODUCTIVE ACRES

THROUGH INTERNATIONAL ENGINEERING...

Nearing completion in northern Peru's Rio Quiroz basin is the San Lorenzo Dam, a massive earth-fill structure that will impound a quarter of a billion cubic meters of water behind its quarter-mile span . . . water to irrigate 60,000 acres of new land through a modern system of canals and laterals.

With sufficient water to bring desert soil to life, farmers will grow premium grade long staple cotton for world markets . . . other crops for local consumption. Water from the San Lorenzo reservoir will also stabilize the irrigation needs of an additional 60,000 acres of farm land now subject to severe droughts and consequent crop losses.

Like so many other water and power projects throughout the world, the Rio Quiroz Irrigation Project was designed and engineered by International Engineering.

SERVING DESIGN & ENGINEERING NEEDS WORLDWIDE WITH

- Reconnaissance and Surveys
- Preliminary Analyses and Evaluation
- Estimates, Financing Plans and Project Recommendations
- Design Drawings and Construction Specifications
- Analysis of Bids and Bid Recommendations
- Detailed Construction Drawings
- General Engineering Supervision
- Final Reports and Record Drawings

INTERNATIONAL ENGINEERING COMPANY, INC.

74 New Montgomery Street • San Francisco, California, U. S. A.
A subsidiary of Morrison-Knudsen Company, Inc.

For a complimentary copy of our 16-page illustrated brochure, write to Dept 2-E.

HERE'S *Versatility* IN ACTION

EIMCO 105
TRACTOR EXCAVATOR

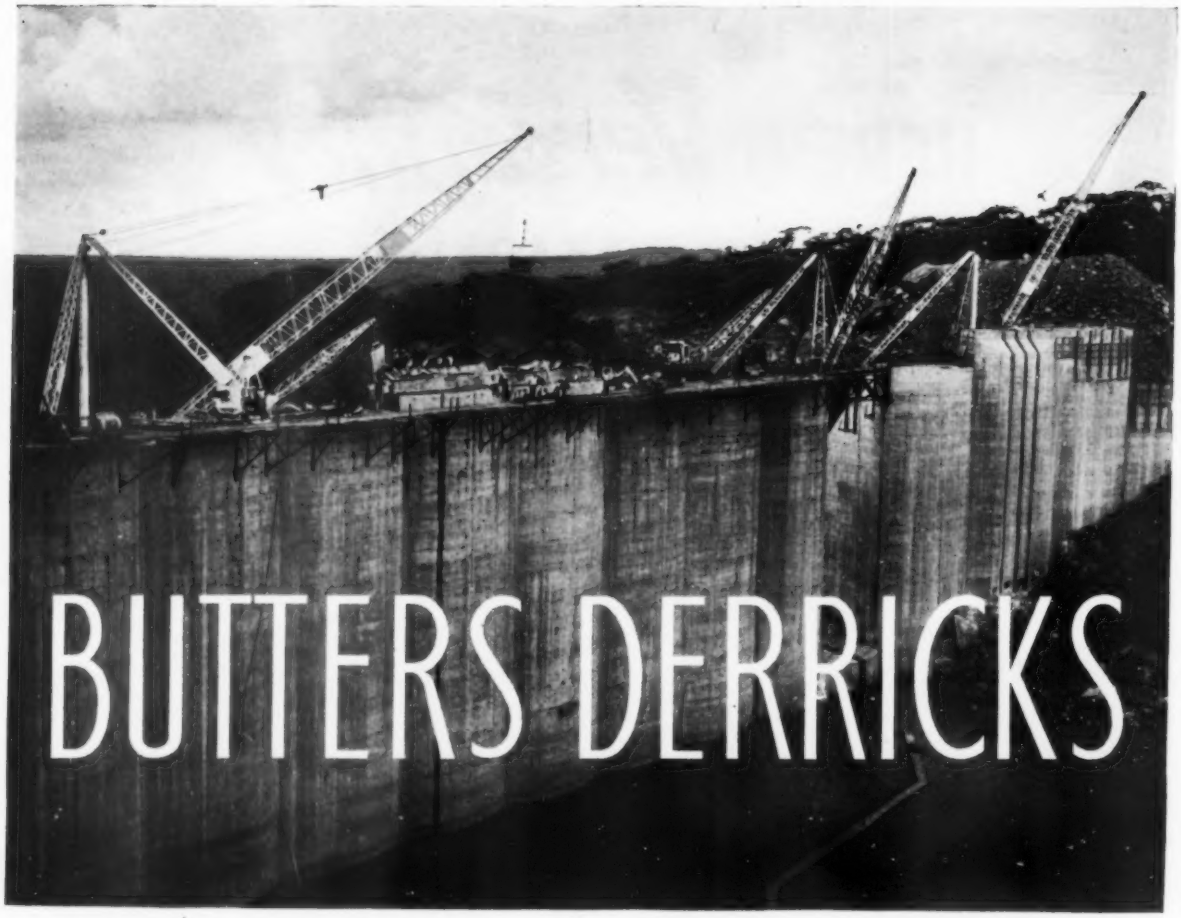
For rock loading, ore handling, in mines and tunnels, on construction jobs or in steel plants, in fact wherever the call is for high speed, dependable loading, the answer is the EIMCO 105 Tractor Excavator. No matter what the conditions, the tough, rugged 105 can take it.

EIMCO

EIMCO (GREAT BRITAIN) LIMITED

Head Office and Works: TEAM VALLEY, GATESHEAD, 11, CO. DURHAM. LOW FELL 7-7241

London Office: PRINCES HOUSE, PICCADILLY, W.1. REGent 2184



The Dam Builders

These pictures show several 7 ton Butters Derrick cranes in use on the construction of a dam in Rhodesia.

The difficult conditions and terrain often encountered in such work demand a very high degree of efficiency in the plant and ability to keep going with minimum maintenance. Butters Derricks have proved ideal—on dam construction all over the world, from New Zealand to the North of Scotland, from Iraq to Eire. Electric, Steam or Diesel drive can be provided in sizes to suit every purpose.

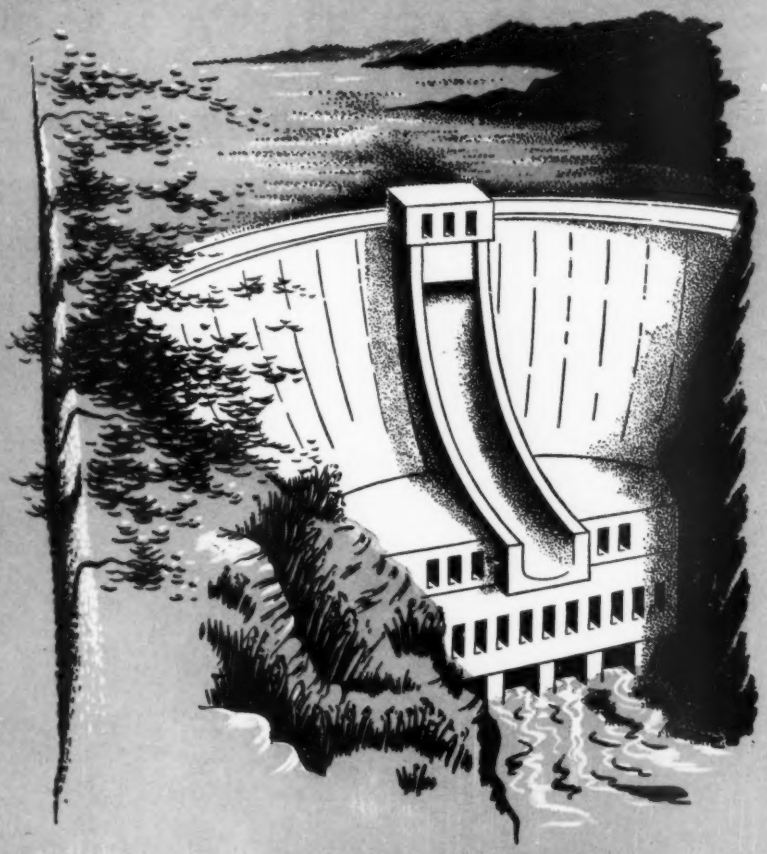
BUTTERS BROS. & Co. LTD.

MACLELLAN STREET *GLASGOW S.1*

Telephone: IBROX 1141 (6 lines) Telegrams: "BUTTERS, GLASGOW"

LONDON: The Crane Works, Long Lane, Hillingdon, Middlesex
Telephone: UXBRIDGE 3925 & 2288

and at BIRMINGHAM and NEWCASTLE



FERRANTI

Transformers for Hydro-Electric Schemes

As specialists in the manufacture of transformers for more than 65 years, FERRANTI LTD. have been associated with many of the world's largest hydro-electric schemes.

More recent achievements include contracts for over 4,000,000 kVA of large high voltage power transformers, among which are :-

CENTRAL AFRICA

Two 120,000 kVA and ten 60,000 kVA 330,000 volts three-phase Transformers have been ordered by the Central African Federation Power Board for the Kariba Hydro Electric Scheme. This is the largest overseas transformer contract ever to be placed in the United Kingdom.

CANADA

Seven 71,000 kVA, 301,400 volt single-phase Ferranti generator transformers and six 37,000 kVA, 275,000 volt step-down Ferranti transformers have been ordered by the Aluminum Company of Canada Ltd. for the Alcan Project at Kemano and Kitimat, British Columbia. Four of the generator transformers and all of the supply transformers are now in commission.

U.S.A.

GARRISON DAM PROJECT Nine 33,333 kVA, 230,000 volt single-phase Ferranti transformers forming three 100,000 kVA banks have been supplied to the U.S. Army Corps of Engineers for the Garrison Dam Project, North Dakota.

McNARY DAM PROJECT Six 56,000 kVA, 230,000 volt, single-phase transformers have been ordered by the U.S. Army Corps of Engineers for the McNary Dam Project, Oregon.

DALLES DAM PROJECT The contract covers eighteen 63,000 kVA, 230 kV and three 63,000 kVA, 115 kV, single-phase transformers for the U.S. Army Corps of Engineers Dalles Dam Project, Columbia River.

NEW ZEALAND

Twenty-six Ferranti large power transformers have been ordered by the State Hydro-Electric Department of New Zealand. Thirteen 14,800 kVA, single-phase, 50 cycles, 11/220 kV transformers have been supplied to Roxburgh, and thirteen 9,259 kVA, single-phase, 50 cycles, 11/220 kV transformers have been supplied to Whakamaru.

INDIA

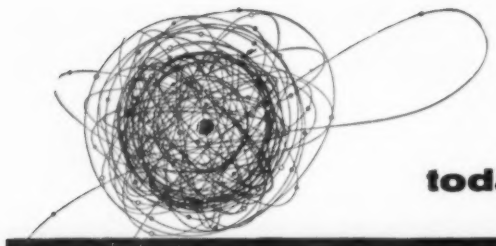
Three Ferranti 20,000 kVA, OFB, 3-phase, 50 cycles, 132/33-66 kV transformers with on-load tap changing gear and two Ferranti 10,000 kVA, ON/OB, 3-phase, 50 cycles, 132/33 kV transformers with on-load tap changing gear have been supplied for the Damodar Valley Power Scheme in India.

F FERRANTI

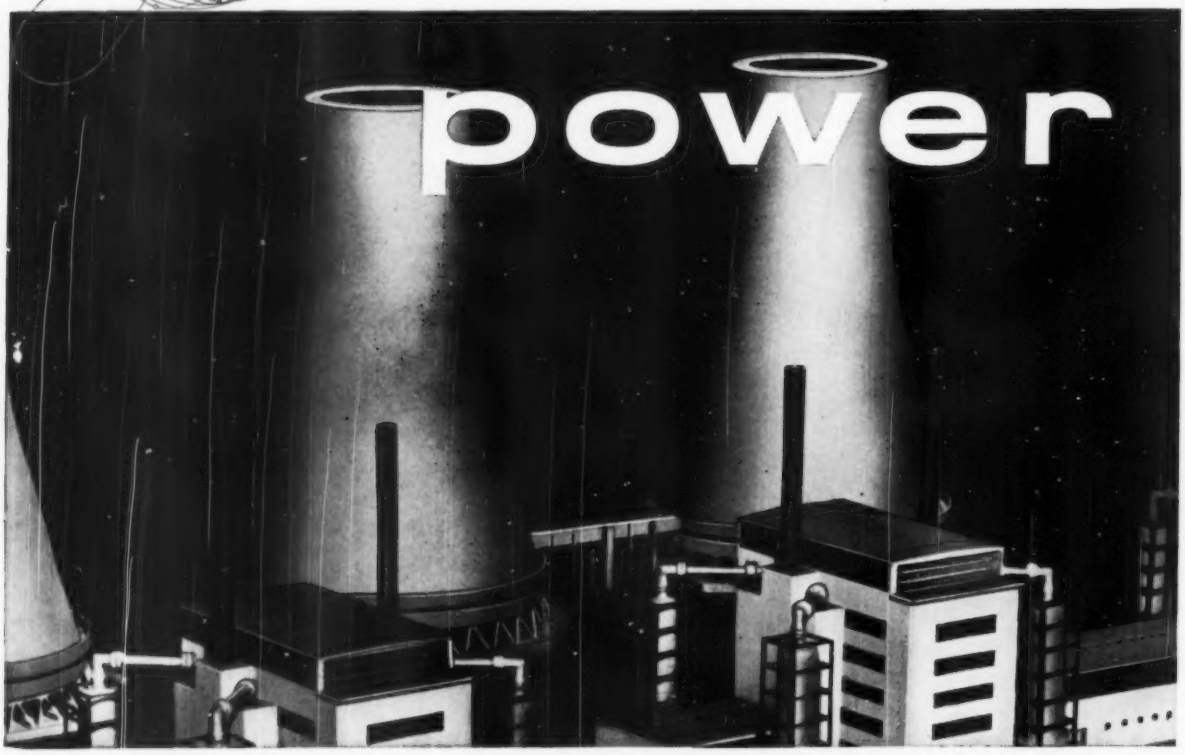
FERRANTI LTD · HOLLINWOOD · LANCS

London Office: KERN HOUSE, 36 KINGSWAY, W.C.2.

FT184/3



today's cables for tomorrow's



HENLEY'S CONTRIBUTION TO THE NEW ATOMIC POWER STATION AT CHAPELCROSS

Nothing is more vital to Britain's future economy than the development of the peaceful atom . . . greater source of controllable power than man has ever before known. Henley's are proud to be associated with the phase of this progress now being planned for Chapelcross, Dumfriesshire. Their contribution will be cables, the arteries along which will course the power that is Britain's life blood . . . and the small but vital cabling for the plant's control and auxiliary circuits. Over 125 miles* in all, representing a £½ million contract.

The shape of Britain's future. How Chapelcross Atomic Power Station will look on completion. We are indebted to Mitchell Construction Company, Peterborough, for permission to reproduce this photograph of part of the model of the project.

*

65,000 yards of H.T. *and* L.T. *Paper Insulated* F.I.N.D. *type cables; 131,500 yards of* V.R. *cables; 27,000 yards of Mineral Insulated Cables. The contract is scheduled for completion by September, 1959.*

CONSULTANTS:
MERZ & McLELLAN,
32 VICTORIA STREET, LONDON, S.W.1

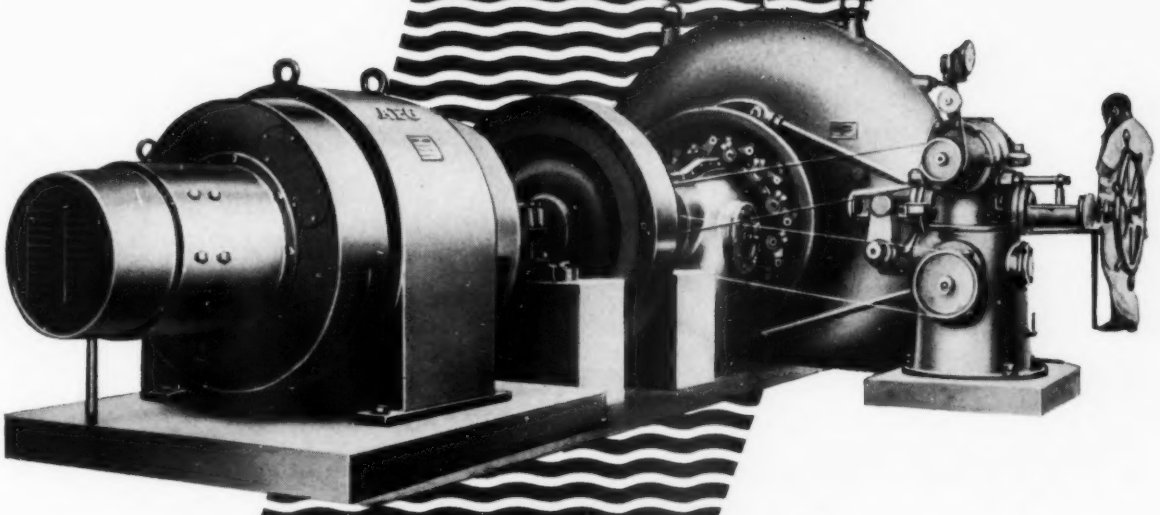
LET HENLEY CABLES CARRY THE CURRENT

W. T. HENLEY'S TELEGRAPH WORKS COMPANY LIMITED, 51-53 Hatton Garden, London, E.C.1.

PEAK ACHIEVEMENTS

with the smaller
as with the larger units

AEG has gained world renown with its large and largest water power alternators. The numerous small water power generating plants in every part of the globe are but further evidence of the advanced state of AEG engineering practice.



Here is a small generating set installed in Central America to feed additional power into an urban system.
AEG Alternator
523 kVA output, at 400 V A. C., direct-coupled to a Francis turbine

AEG
means
ELECTRICITY

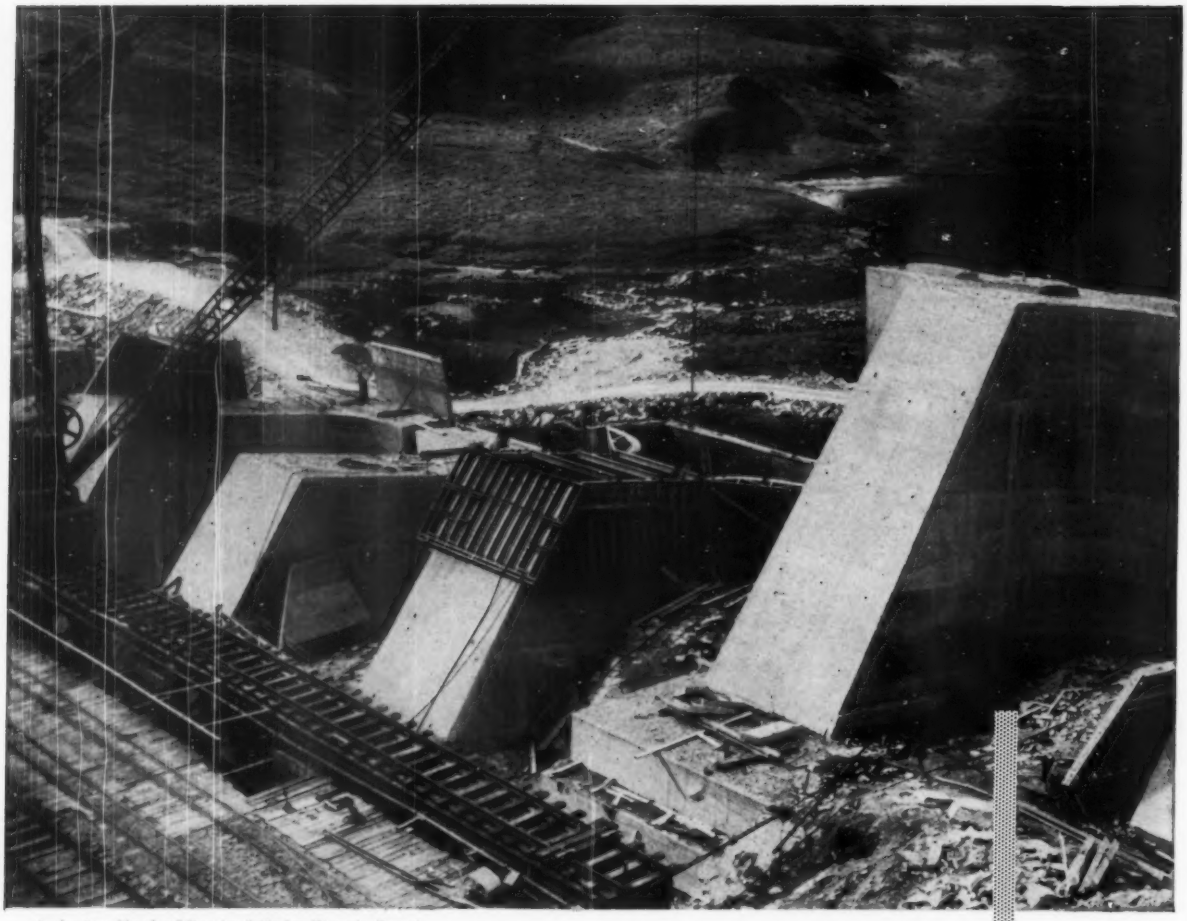
Agents in all large cities of the world

Agent for Great Britain:
WELMEC CORP. LTD.
147, Strand
London W. C. 2

7940e

ALLGEMEINE ELEKTRICITÄTS-GESELLSCHAFT

Berlin (West) EXPORT DEPARTMENT Frankfurt (Main)



Authority: North of Scotland Hydro Electric Board
Consulting Engineers: James Williamson & Partners

THE GIORRA DAM

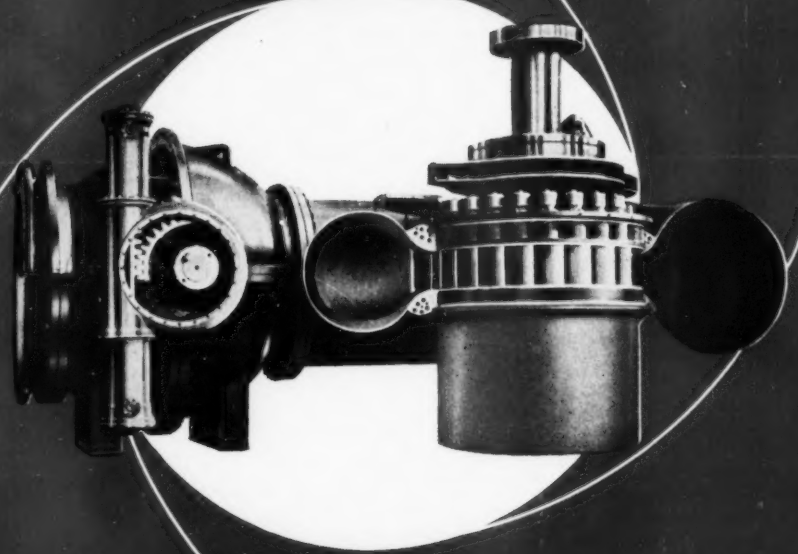
The 1,450 foot long and 100 foot high dam at the eastern end of Loch Giorra is an important part of the Killin Section of the North of Scotland Hydro-Electric Board's Breadalbane Power Scheme. Edmund Nuttall are the contractors for this work and the photograph shows an early stage in concreting on the buttresses of the Dam.

EDMUND NUTTALL

CIVIL ENGINEERING CONTRACTORS

EDMUND NUTTALL, SONS & CO. (LONDON) LTD. 22 GROSVENOR GARDENS, LONDON S.W.1. TELEPHONE: SLOANE 0030

COMPLETE EQUIPMENT FOR WATER POWER PLANTS

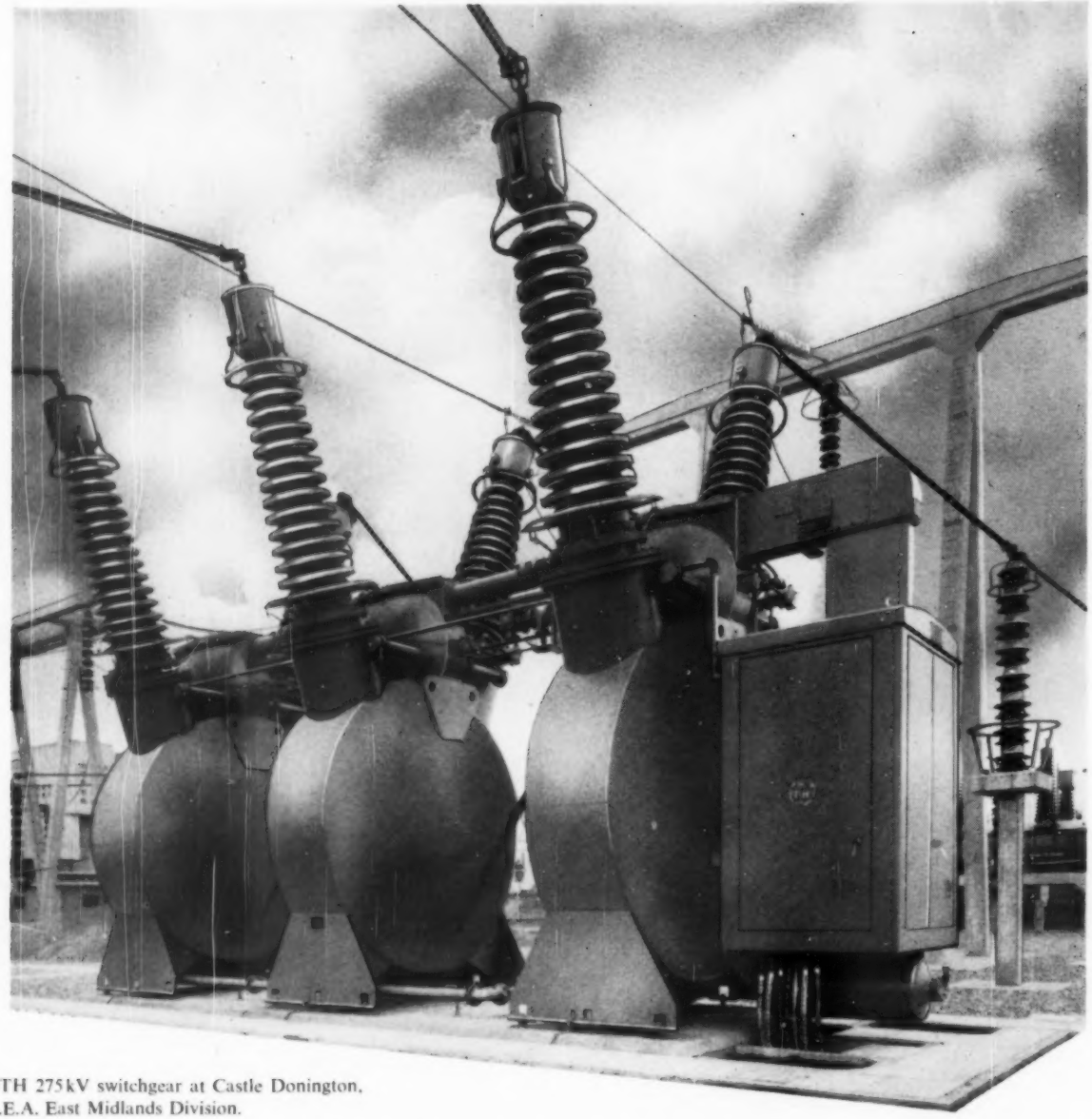


Turbines of the Francis, Kaplan and Pelton type for various heads and outputs, transformers, generators, outdoor and indoor switch-gear, control-rooms, etc.

The world-known ŠKODA and ČKD trade-marks guarantee the first-class technical design and quality of equipment supplied by us. We give integral guarantees for complete deliveries.

TECHNOEXPORT

Foreign Trade Corporation for Export of Complete Industrial Plants
54, Václavské náměstí, Praha II.,
CZECHOSLOVAKIA



BTH 275kV switchgear at Castle Donington,
C.E.A. East Midlands Division.

B T-H

330-kV SWITCHGEAR
for
KARIBA

The two million pound order awarded to British Thomson-Houston for the Kariba Hydro-electric Scheme includes 23 oil circuit-breakers of the BTH lenticular type. These units are a direct development of those installed on the 275kV British Super-Grid.

BRITISH THOMSON-HOUSTON

THE BRITISH THOMSON-HOUSTON COMPANY LIMITED · WILLESDEN · ENGLAND

Member of the AEI group of companies

A5079

Water Power Experts all over the World rely on Steel Castings and Forgings made by Bochumer Verein

We manufacture and supply

Steel Castings: Plain carbon steel up to 400 tons;
13% Cr and other alloyed steel up to 120 tons cast weights.

Steel Forgings: Plain carbon and alloyed steel up to 150 tons ingot weight.

BV-Vacuum Steel
for complicated and highly stressed castings or those exposed to cavitation and for highly stressed forgings

Bochumer Verein
für Gusstahlfabrikation AG. BOCHUM

Postbox 325, Bochum (Germany) · Telegrams: Gusstahl · Teleprinter: Gusstahl 0825831

CHARMILLES

CHARMILLES ENGINEERING WORKS LTD. - GENEVA

31 000 HP
RUNNER FOR THE HIGHEST HEAD
in the world
5,800 FEET

The highest head
in AMERICA
3,700 FEET
is also equipped with
CHARMILLES TURBINES
LOS MOLLES POWER PLANT
Two 12,650 HP units

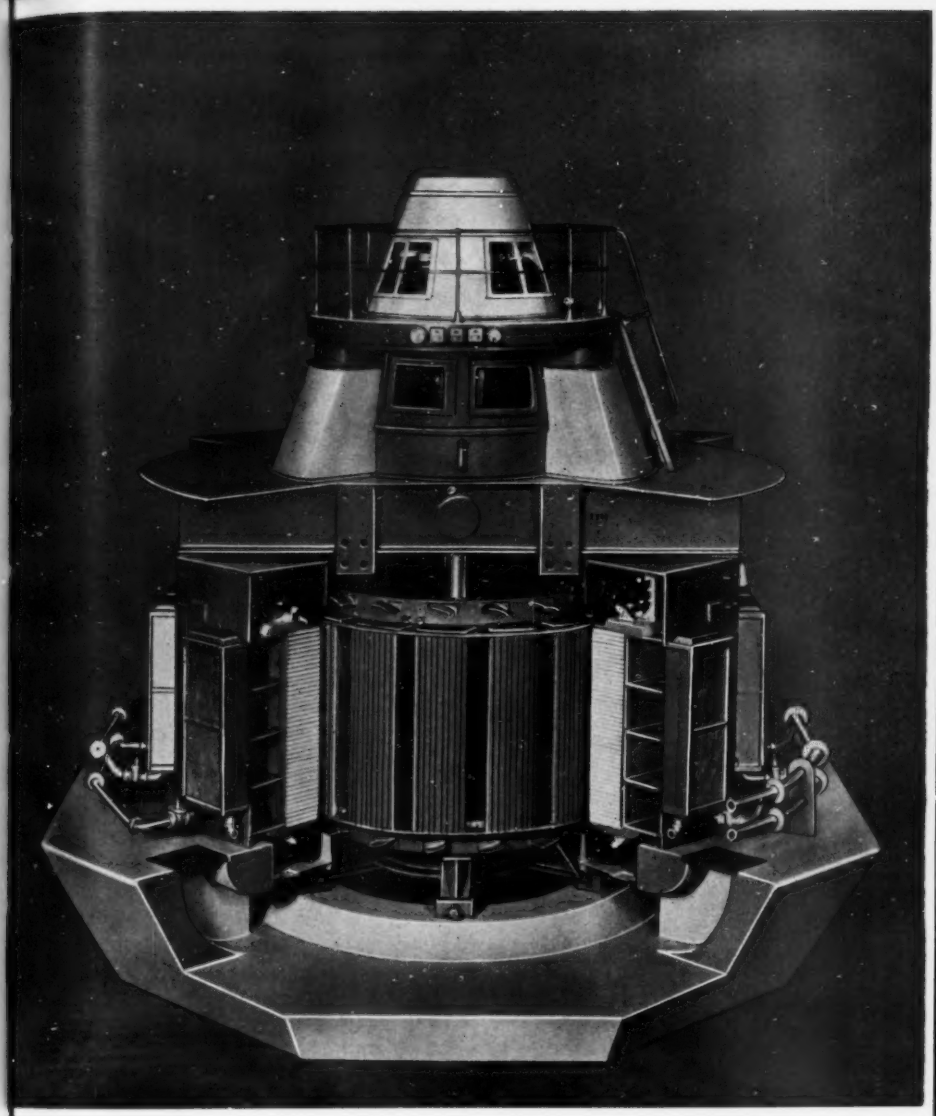
EXCERPT
FROM CHARMILLES
REFERENCE LIST

THE SIXTEEN HIGHEST HEAD TURBINES IN THE WORLD

Installation	Number of units	Net head feet	Unit output HP
Reisseck (Austria)	3	5,800	31,000
Dixence (Switzerland)	5	5,700	50,000
*Fully (Switzerland)	4	5,400	3,000
Miéville (Switzerland)	3	4,730	47,500
Portillon (France)	1	4,280	53,500

*manufactured in the time of Pic-Pic

No other turbine in the world operates with a head equal to or higher than any of the above



4 × 84,210 + 4 × 75,700 kVA for Australia

The largest water-turbine-driven generators in the Southern Hemisphere

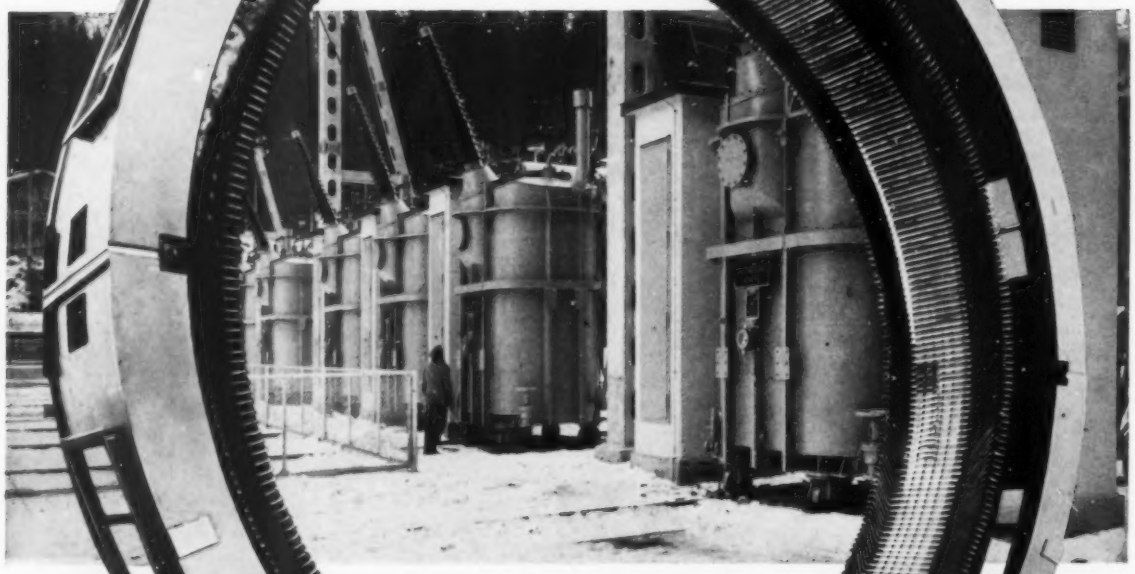
In the face of very keen international competition ASEA was awarded in 1954 by the Snowy Mountains Hydro-Electric Authority, Sydney, Australia, the contract for four three-phase generators, each with a rating of 84,210 kVA, 375 r/m, for the T 1 power-station on the River Tumut. In 1957 this contract was followed by yet another for four generators, each rated at 75,700 kVA, 428 r/m, for the T 2 power-station on the same river. These power-stations form part of the largest civil-engineering project ever to have been carried out in Australia, and the machines are indeed the largest water-turbine-driven generators in the Southern Hemisphere.

ASEA has now delivered or is in the process of manufacturing twenty-eight generators with ratings exceeding 75,000 kVA. The average output of these machines is almost 94,000 kVA, and the three largest, which each have an output of 150,000 kVA, are believed to be the biggest in the world at present.

If you are considering the expansion of your present plants or the construction of new power-stations, it is in your interest to consult us. We have the experience, resources and delivery capacity to satisfy your requirements.

Västerås ASEA Sweden

Hydro-Electric Power Station Equipment



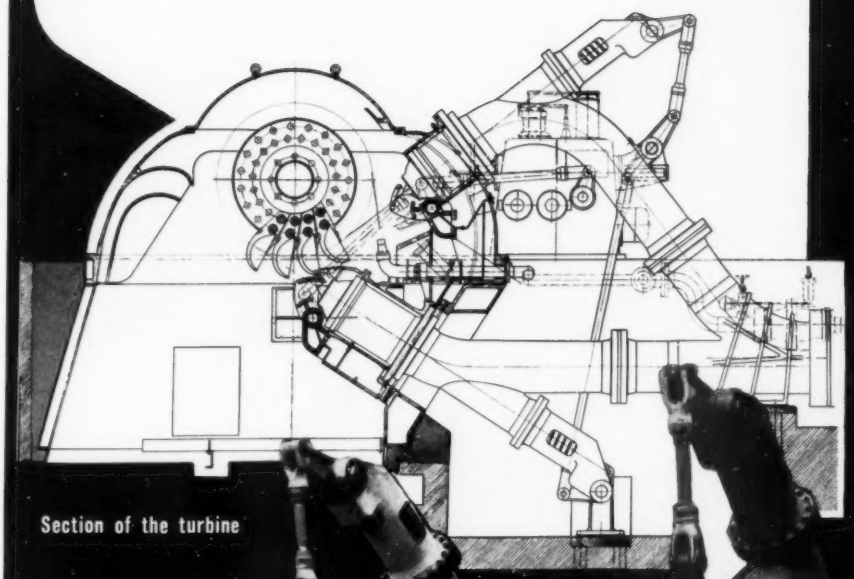
Sécheron

Generators and motors with capacities above 150 kW. Single-phase and three-phase transformers for all outputs and voltages. Electrical applications in the field of traction. Installations of pumpless mercury arc rectifiers with rare gas filling. High-speed automatic regulators applied to various control problems. Welding rods and electric arc welding sets.

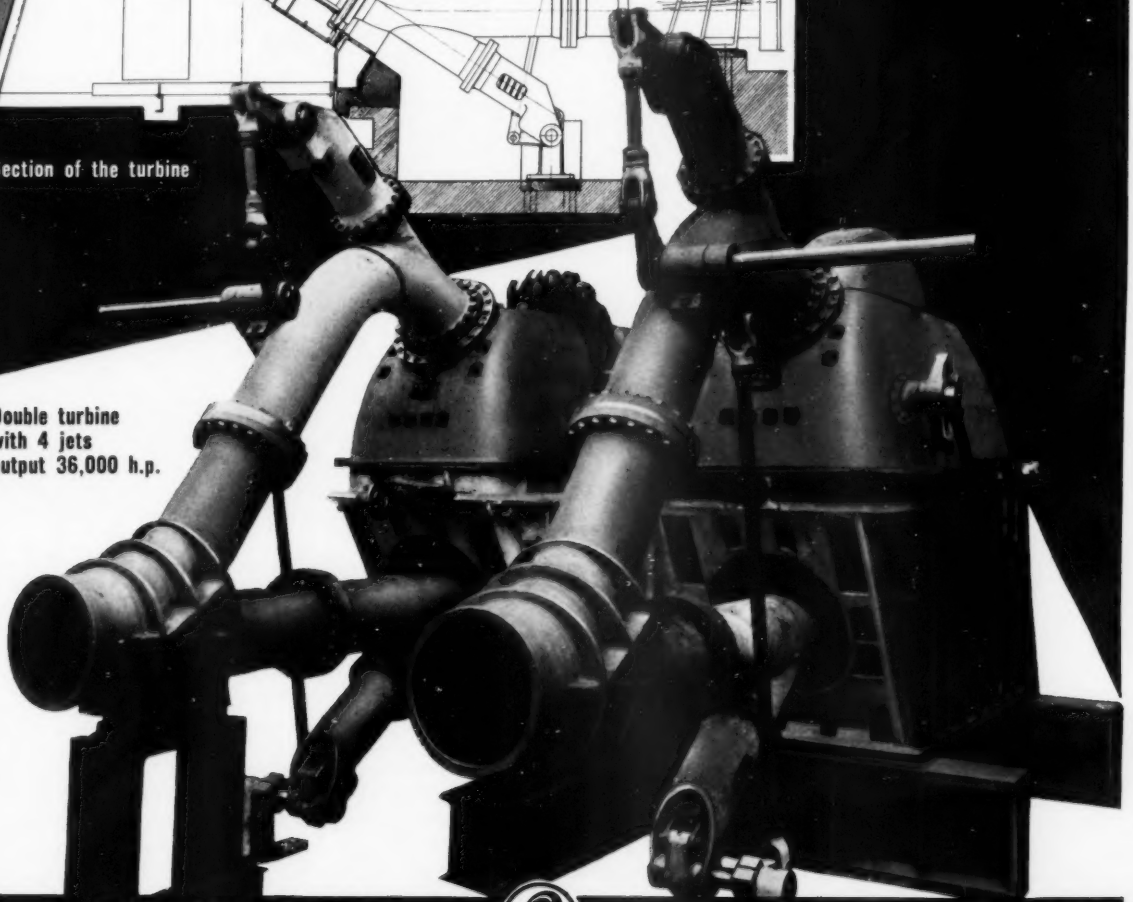
S.A. des Ateliers de Sécheron, Geneva

Pelton-Turbines

AS DOUBLE TURBINES WITH 4 JETS UP TO THE MAXIMUM OUTPUTS INCLUDING REGULATING EQUIPMENT AND SHUT-OFF DEVICES



Section of the turbine



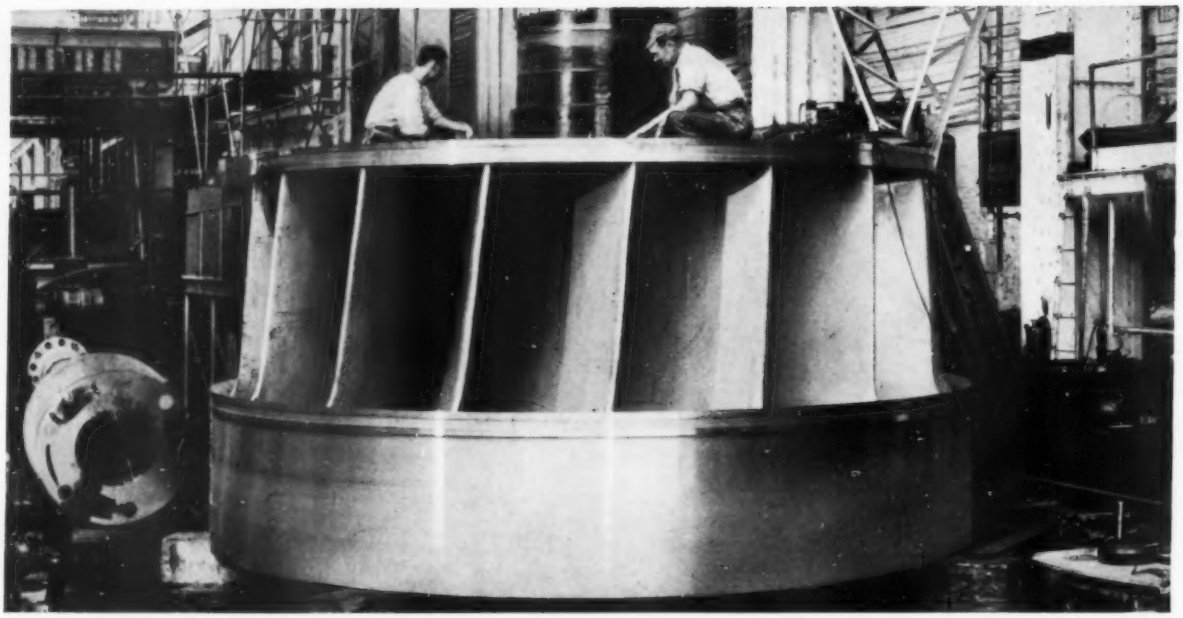
Double turbine with 4 jets output 36,000 h.p.

J.M. VOITH AUSTRIA

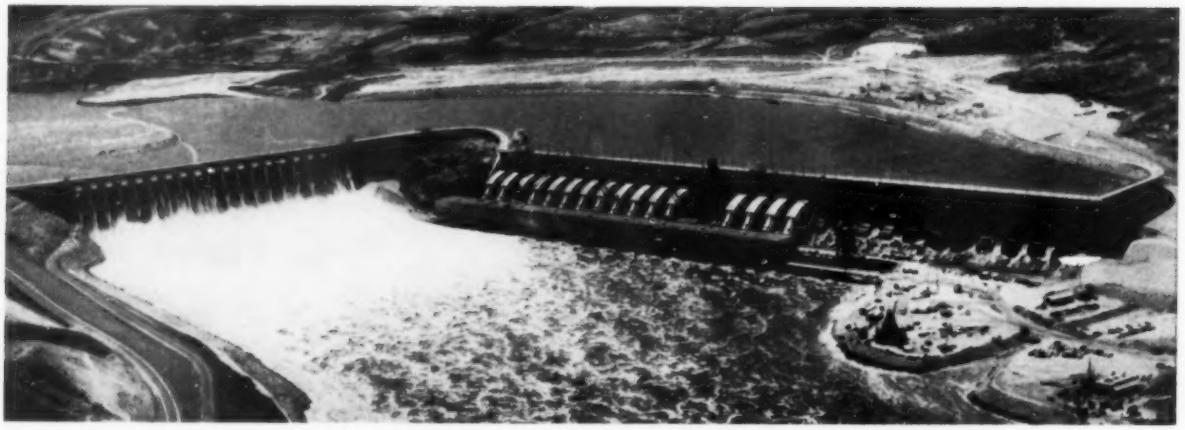
ST. POELTEN P.O.B. 168 TELEPHONE 2501

TELETYPE 01 2148 TELEGRAM ADDRESS: VOITHWERK ST. POELTEN

TLL 674/e



Newport News builds 10 unique runners



For Chief Joseph Dam in Washington State

Cast buckets are welded to cast crown and band—then stress relieved

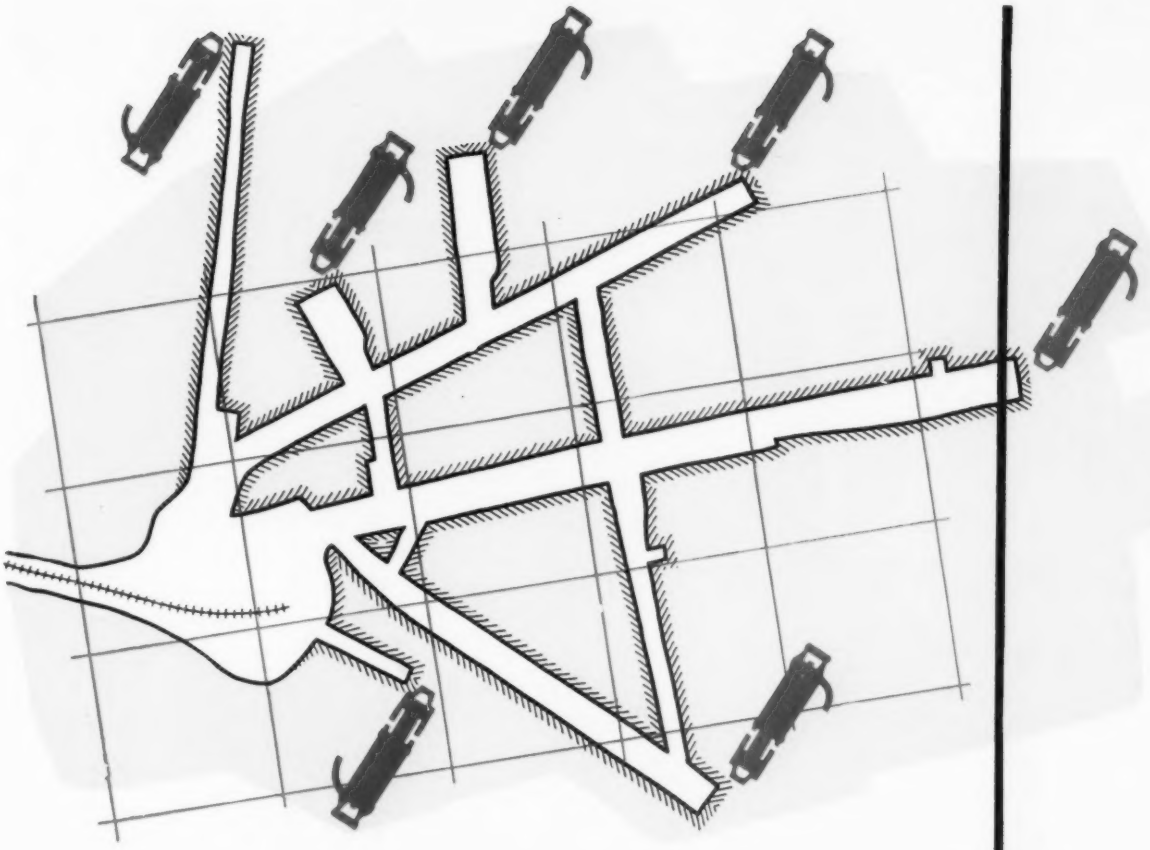
The Francis-type runner above illustrates Newport News' complete facilities for fabricating heavy equipment.

It also illustrates the specialized techniques Newport News frequently uses in jobs of this type. Gibson tests for these units are very favorable.

Before you go ahead on a project like this, be sure to get a bid from Newport News. Whether it's penstocks, butterfly valves, pumps or turbines, you'll get the benefit of the modern plant methods and production facilities of one of the country's oldest and largest builders of water power equipment.

Engineers. . . Desirable positions available at Newport News for Designers and Engineers in many categories. Address inquiries to Employment Manager.

Newport News
Shipbuilding and Dry Dock Company
Newport News, Virginia



Fast working Holman Silver Three makes tough jobs easier — and cheaper

When you're drilling against time and the going is tough — you need Silver Threes. For sheer speed and sheer guts there's nothing to beat the Silver Three. That was proved when Mitchell Construction used four Silver Threes to smash the World Tunnelling Record by driving their Breadalbane tunnel 557 feet in one week.

We provided five drills. The fifth was a reserve but it was never needed. The four drills (straight production jobs) slammed away without a murmur.

It's this speed, and the ability to work hard and long without cracking up, that makes the Silver Three a slayer of running cost. And it's running cost that's the *real* cost of a drill.

Get Silver Threes and you'll get through the work at speed. You'll save hours on the timesheets and you'll save a mint of money.

Holman
PNEUMATIC EQUIPMENT

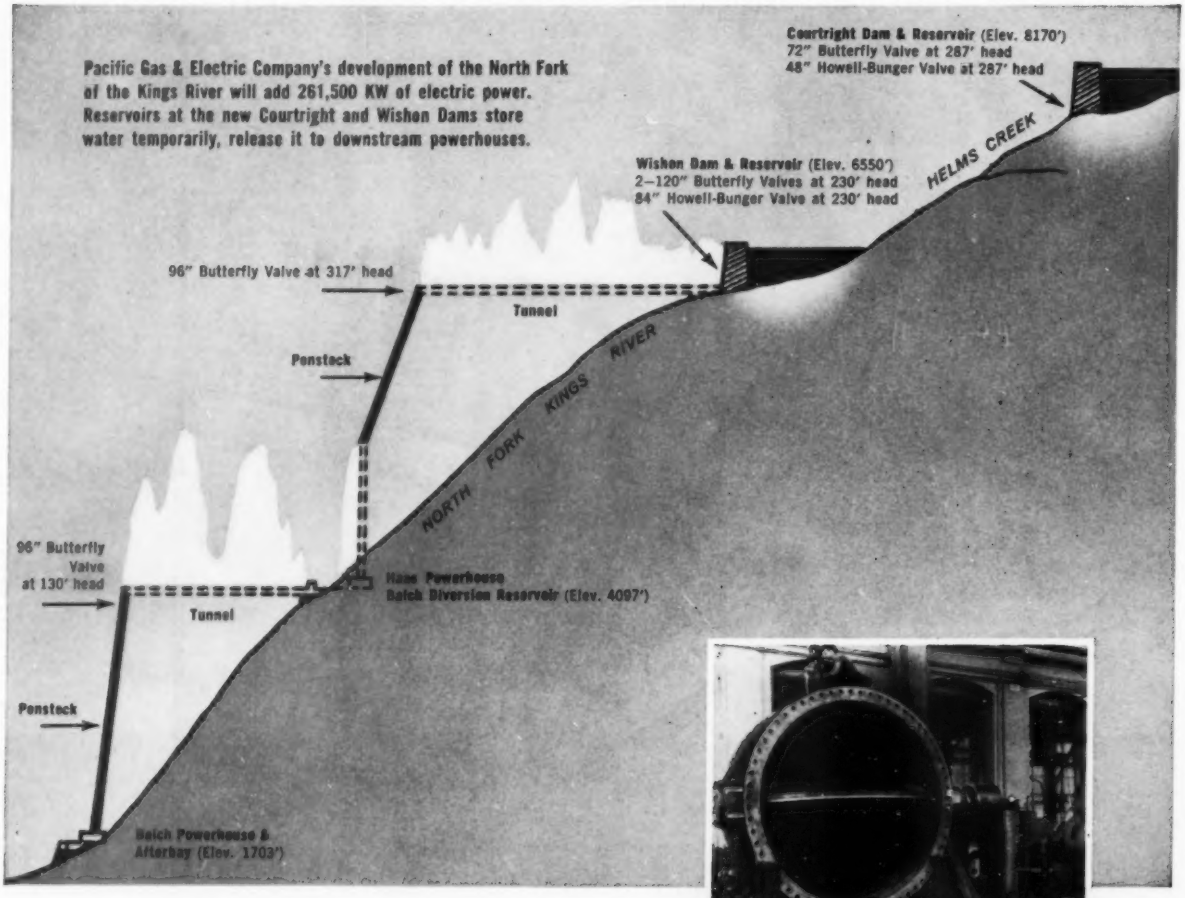
pays . . . with its life

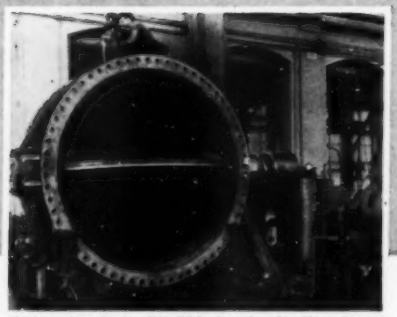
HOLMAN BROS. LTD., CAMBORNE, ENGLAND

The Holman Organisation is world-wide. It includes the Climax Rock Drill & Engineering Works Ltd., and has agents, branches and technical representatives throughout the United Kingdom and in 84 other countries.

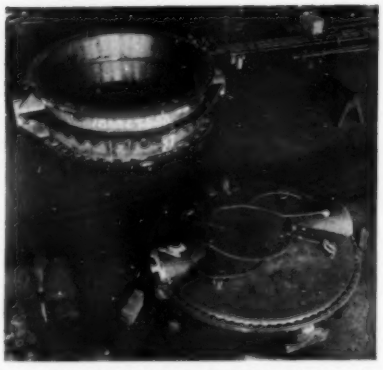
Telephone: Camborne 2275 (10 lines). Telegrams: Airdrill, Telex, Camborne. London Office: 44 Brook Street, W.1. Telephone: Hyde Park 9444

HJ39


Pacific Gas & Electric Company's development of the North Fork of the Kings River will add 261,500 KW of electric power. Reservoirs at the new Courtright and Wishon Dams store water temporarily, release it to downstream powerhouses.
Courtright Dam & Reservoir (Elev. 8170')
72" Butterfly Valve at 287' head
48" Howell-Bunger Valve at 287' head
HELMS CREEK
Wishon Dam & Reservoir (Elev. 6550')
2—120" Butterfly Valves at 230' head
84" Howell-Bunger Valve at 230' head
96" Butterfly Valve at 317' head
Tunnel
Penstock
NORTH FORK KINGS RIVER
96" Butterfly Valve at 130' head
Haas Powerhouse
Balch Diversion Reservoir (Elev. 4097')
Tunnel
Penstock
Balch Powerhouse & Afterbay (Elev. 1703')



During shop tests, the 96-inch valve for Haas tunnel demonstrates the streamlined construction of SMS welded steel plate discs. This reduces head loss and turbulence to a minimum.



One of the 120-inch Wishon Reservoir valves on the SMS assembly floor shows adjustable seals on the discs and recess for the renewable seal ring within the body.

Kings River Project installs SMS valves

Five SMS Butterfly Valves and two SMS Howell-Bunger Valves are being installed by Pacific Gas & Electric Company on its Kings River hydropower project in the Sierra and Sequoia National Forests. They will control the flow of water from upstream reservoirs to the powerhouses in this $80 million system.

Seals on SMS Butterfly Valves cut leakage to a minimum. Disc and body seals are adjustable from either inside or outside, as specified. Specially-developed SMS trunnion seals are essentially drop-tight. Welded discs and housings assure freedom from the defects of cast materials, and permit more economical construction.

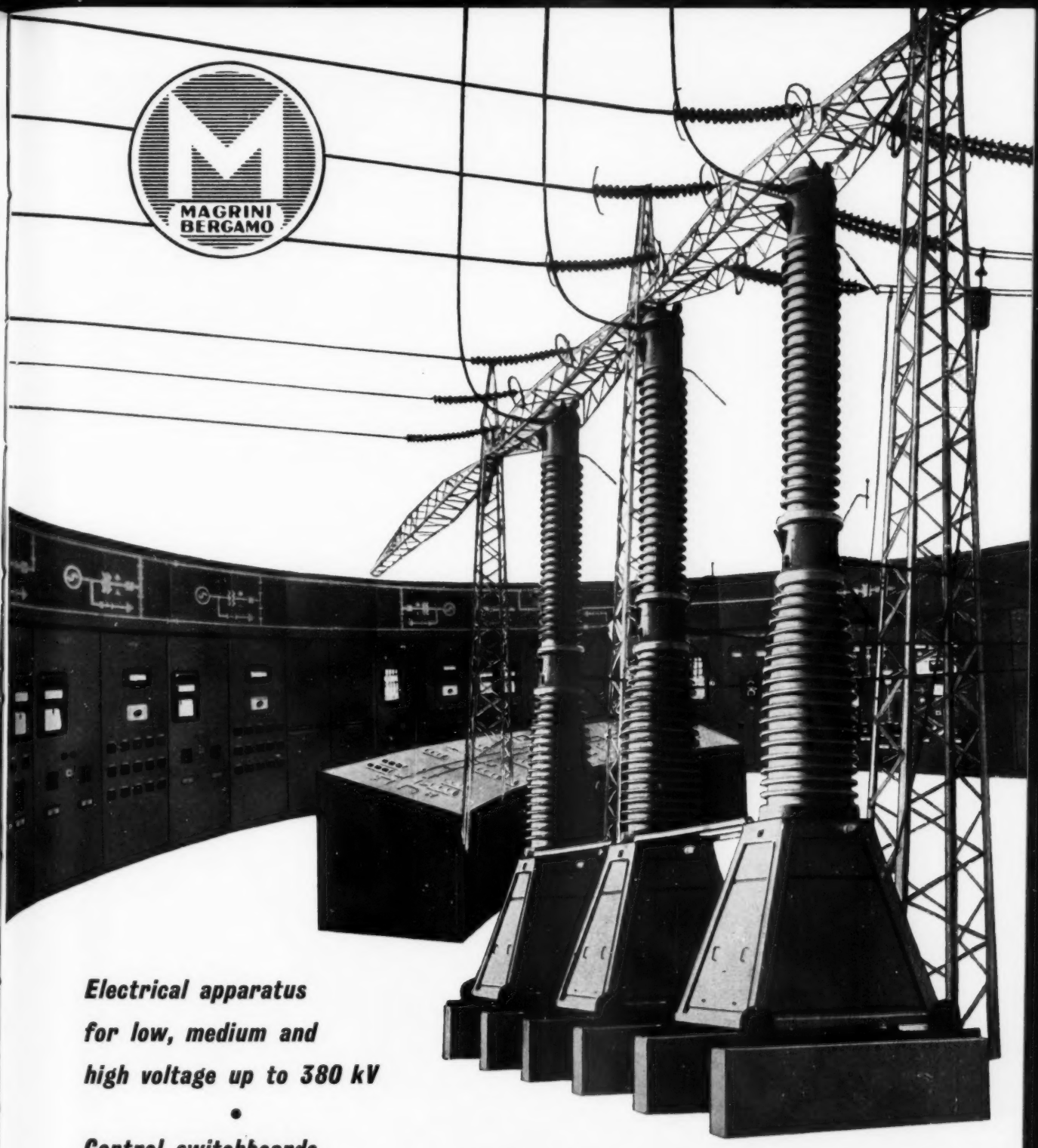
SMS Butterfly Valves have been designed and built in diameters up to 18 feet, and for service with operating heads up to 750 feet. To obtain information on SMS hydraulic turbines, valves and other accessories, write to S. Morgan Smith Company, York, Penna.

S. MORGAN SMITH HYDRODYNAMICS More Power To . . .

AFFILIATE: S. MORGAN SMITH, CANADA, LIMITED, TORONTO

Licensees: The Harland Engineering Company, Ltd., Alloa, Scotland • Tokyo Shibaura Electric Co., Ltd., Japan

Rotovalves • Ball Valves • R-S Butterfly Valves • Free-Discharge Valves • Liquid Heaters • Pumps • Hydraulic Turbines & Accessories



Electrical apparatus
for low, medium and
high voltage up to 380 kV

•

Control switchboards
and control desks

•

Indoor and outdoor
metal clad switchgear

•

Lightning arresters

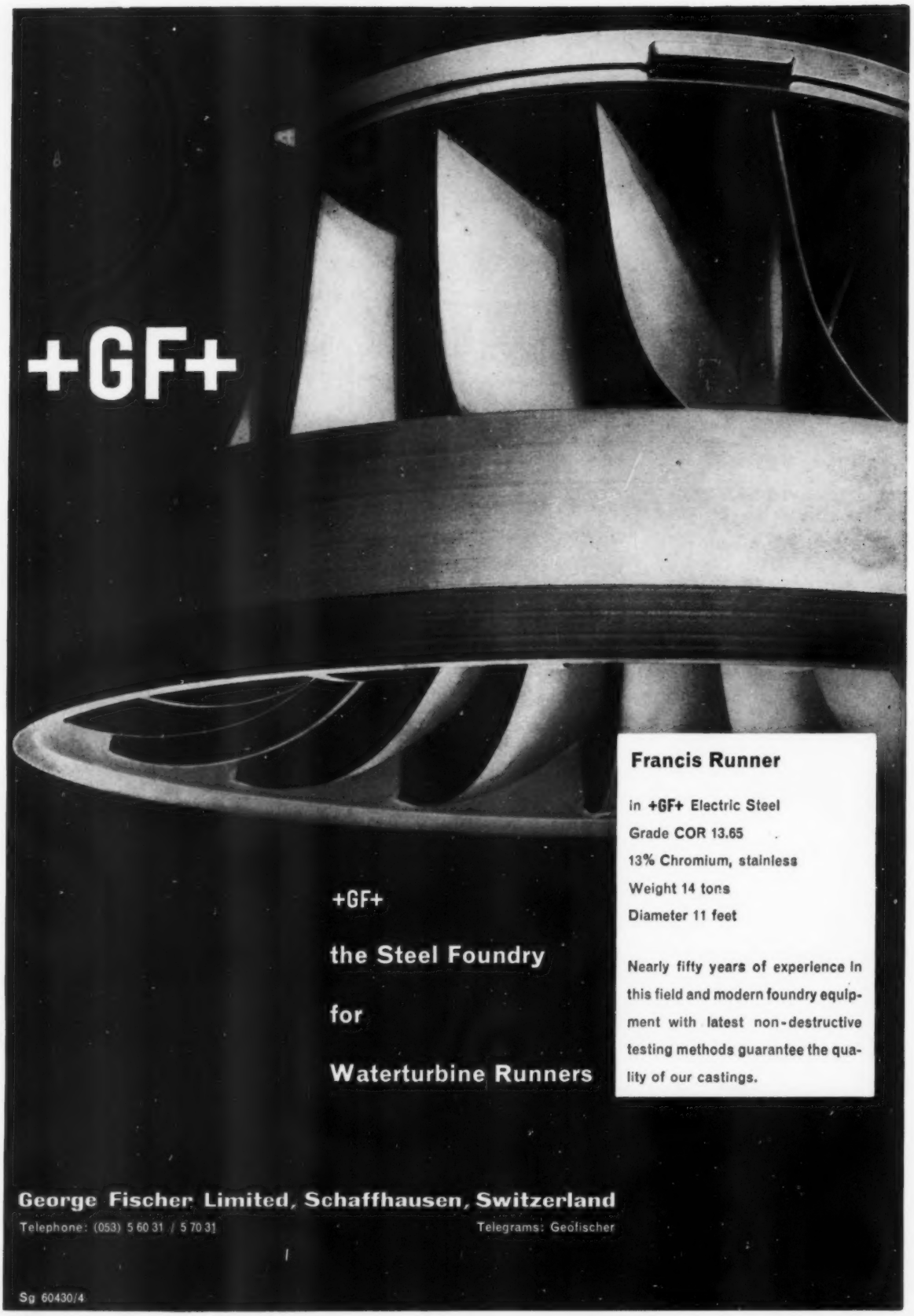
MAGRINI

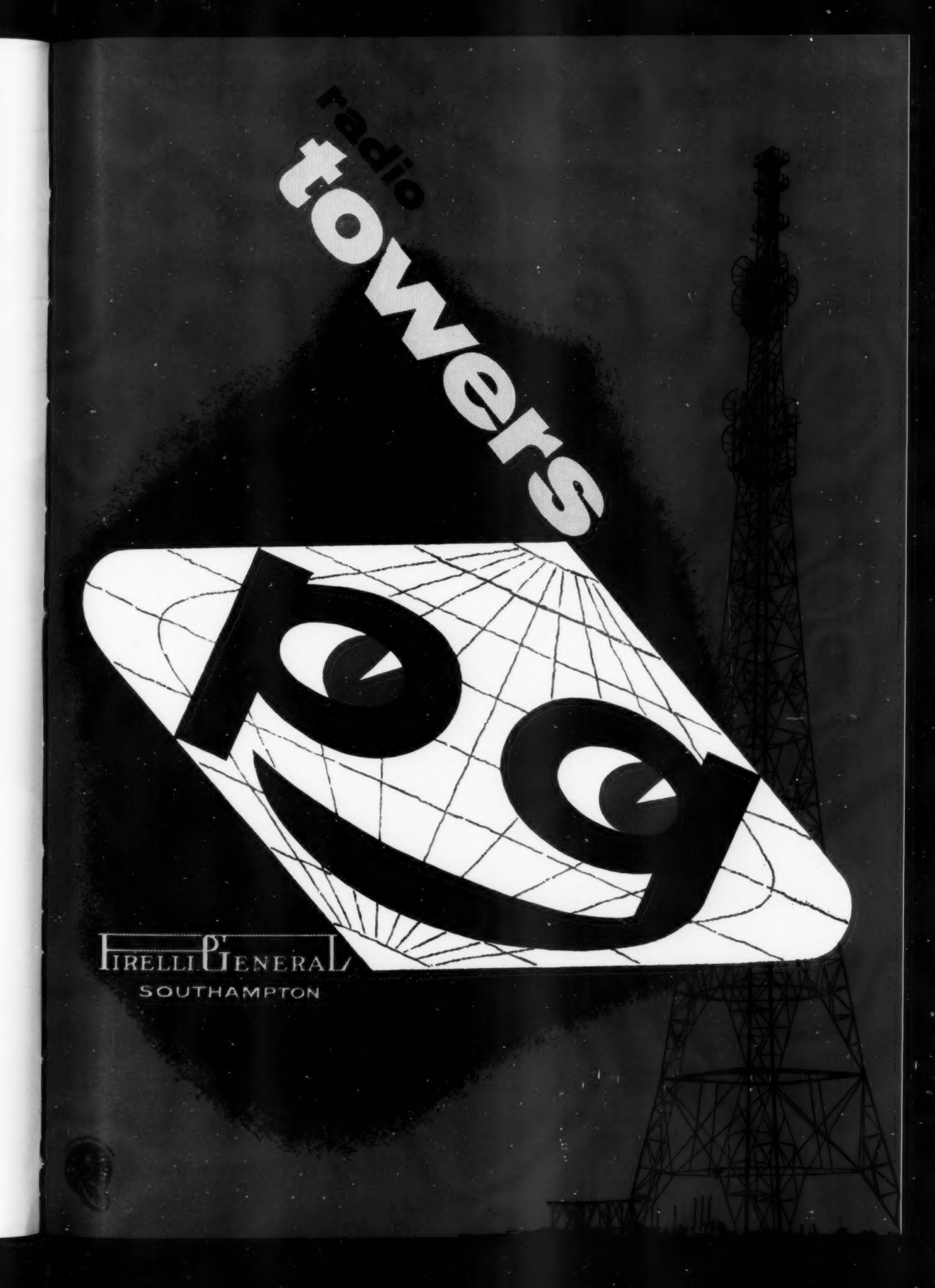
S.p.A.

EXPORT SALES, HEAD OFFICE AND WORKS—

BERGAMO (ITALY) - VIA L. MAGRINI, 7 - PHONE 22.168

SALES AGENTS IN ITALY AND ABROAD

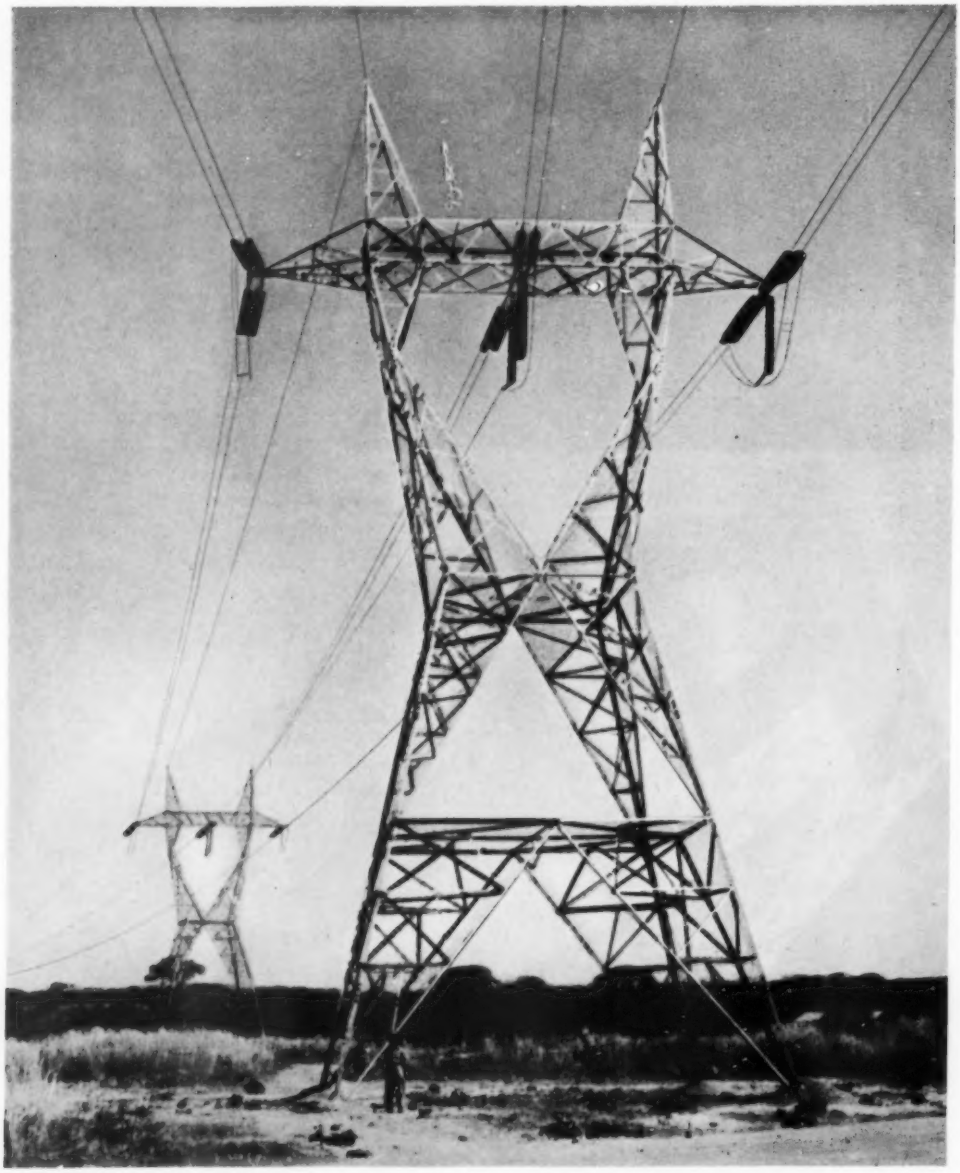

+GF+
Francis Runner
in +GF+ Electric Steel
Grade COR 13.65
13% Chromium, stainless
Weight 14 tons
Diameter 11 feet
Nearly fifty years of experience in this field and modern foundry equipment with latest non-destructive testing methods guarantee the quality of our castings.
+GF+
the Steel Foundry
for
Waterturbine Runners
George Fischer Limited, Schaffhausen, Switzerland
Telephone: (053) 5 60 31 / 5 70 31
Telegrams: Geofischer
Sg 60430/4


radio
towers
PG
PIRELLI GENERAL
SOUTHAMPTON

"VOLPATO"

COMPLETE EQUIPMENT FOR H.V. LINES FROM 30 KV TO 380 KV
SUB STATIONS AND POWER PLANTS · COMPRESSION MATERIAL

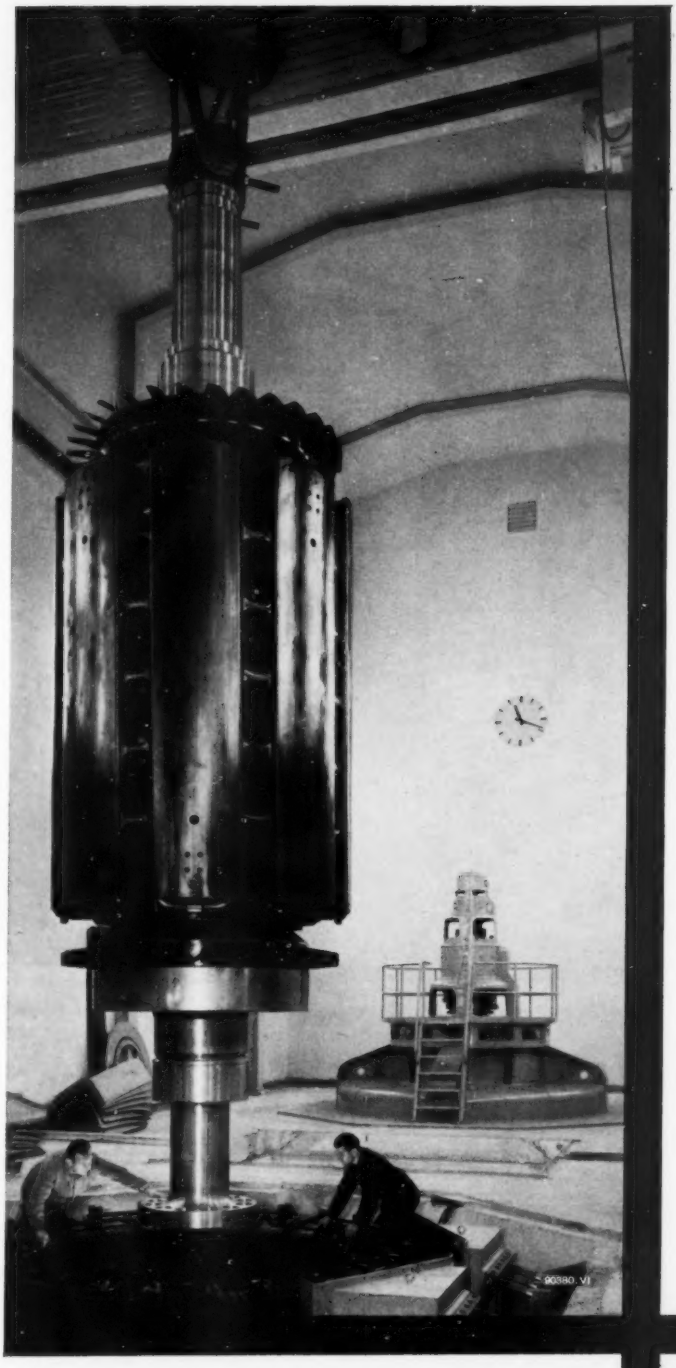
HIGH-GRADE SPECIALIZED MANUFACTURERS — 35 YEARS OF EXPERIENCE



TOTAL EQUIPMENT FOR THE LONGEST 220 kV OVERHEAD LINE IN AFRICA - Connecting Haut Katanga (Belgian Congo) to Northern Rhodesia - (Le Marinel - Jadotville - Kitwe) Twin Conductors - 510 km

SOC. ELETTRO-MORSETTERIE VOLPATO - VIA B. CAVALIERI. 3 - MILANO - ITALY

CATALOGUES AND PRICES ON REQUEST



Brown Boveri leaders in the design of high-speed salient-pole waterwheel generators

Lowering the rotor into the second alternator at the Fionnay Power Plant in Switzerland, owned by the Forces Motrices de Mauvoisin, S.A., Sion, where three generators rated 60 MVA, 0.8 p.f., 750 r.p.m., 10.5 kV, 50 c/s are being installed.

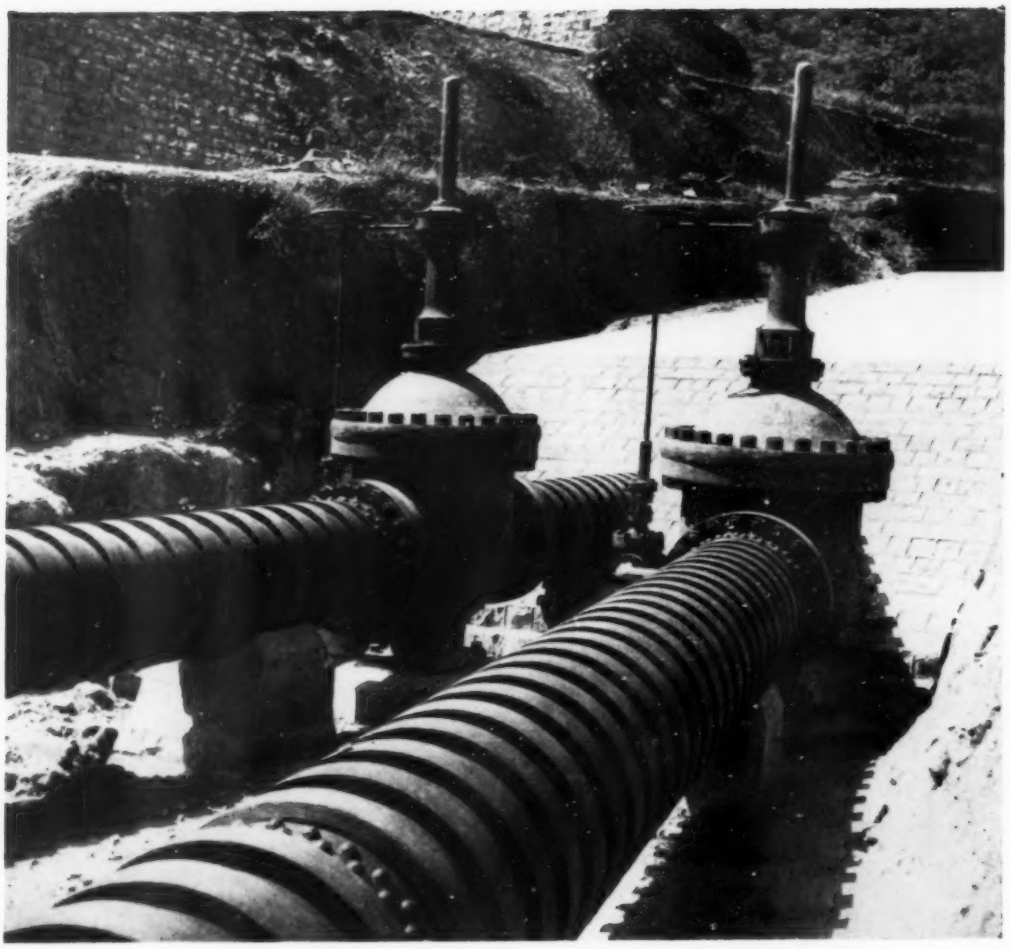
Some high-speed waterwheel generators at present under construction, or recently installed:

No. of Units	Output kVA	Shaft	Speed r.p.m.	Power Station	Country
1	23 000*	V	1 000	Oberaar	Switzerland
2	20 000	H	1 000	Ernen	Switzerland
3	60 000	V	750	Fionnay	Switzerland
3	29 000	H	750	Motec	Switzerland
1	30 000	V	750	Piottino	Switzerland
3	57 500	V	720/600	Tingambato	Mexico
1	60 000	V	600	Paradela	Portugal
2	45 000	V	600	Hemsil II	Norway
3	17 650	V	600	Neriamangalam	India

* Synchronous motor

BROWN BOVERI

BROWN, BOVERI & CO., LTD.
BADEN
SWITZERLAND



In the pipelines

ISOLATING VALVES

Sluice Valves for isolation service on penstocks usually have to be specially made to suit the site conditions. For high heads we recommend round-bodied, parallel-faced units and for medium and low pressures oval-bodied valves with wedge shaped doors.

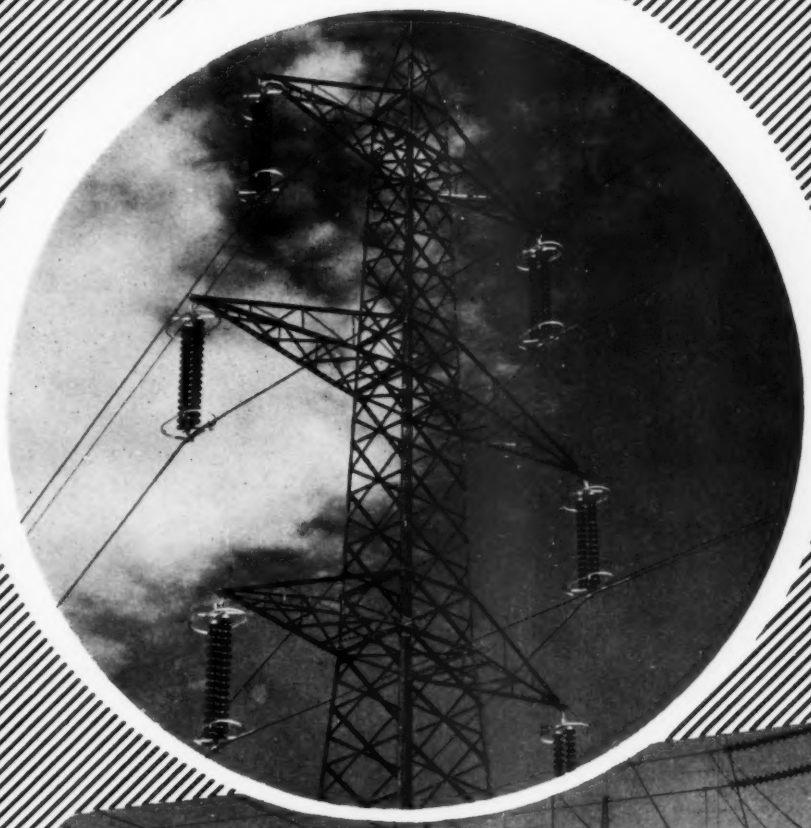
Illustrated are two Glenfield cast-iron round-bodied parallel-faced isolating valves, designed to maintain a maximum unbalanced head of 3,050 ft., on the Pykara Hydro-electric Scheme, India.

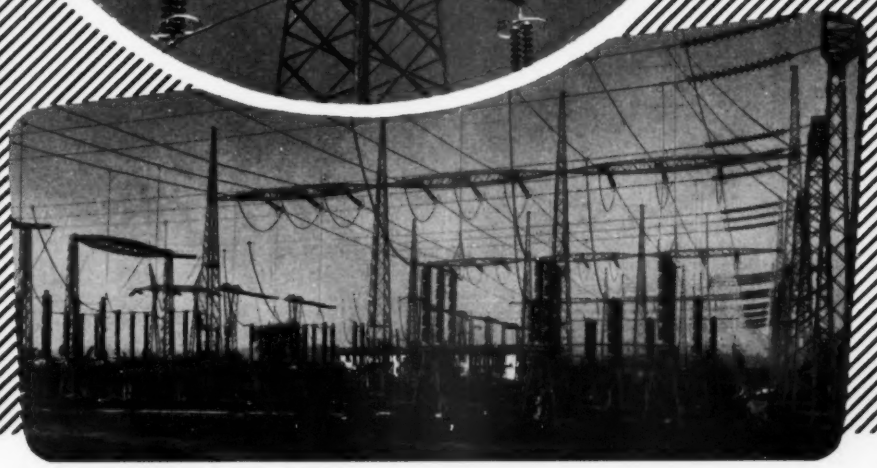
Glenfield

GLENFIELD & KENNEDY, LIMITED, KILMARNOCK

Head Office & Works: KILMARNOCK, SCOTLAND

SALVI





For 30 years Messrs. A. Salvi and Company, Milano, Italy, have specialized in the design and manufacture of complete equipment for Overhead Transmission Lines, including Compression Dead End Assemblies and Joints.
The Works of the Salvi Company are engaged exclusively in the production of high grade fittings for High Voltage Transmission Systems, up to and including voltages of 220/380 KV and for all sizes of Copper, A.C.S.R. and Aluminium Alloy Conductors.

SOLE REPRESENTATIVES IN THE UNITED KINGDOM AND THROUGHOUT ALL DOMINION COUNTRIES
(EXCEPT AUSTRALIA AND NEW ZEALAND) AND BRITISH COLONIES AND PROTECTORATES

THE ENGLISH SALVI COMPANY LTD., 11 Kensington Church St., London, W.8

Telephones: WEStern 8857 and 4412 Cables: ENSALVICO LONDON

Child's play is man's work

A stream flowing along its pebbly course, is to a boy a mighty torrent, whose gurgling challenge must be met. With stones and mud, and many a frantic plugging, a dam is built. In the same spirit man faces the challenge of harnessing nature, and spurred by vital purpose it becomes his daily work. We of Harland Engineering are building hydro-electric plant, pumps, turbines, motors and generators and all manner of plant for the increasing of life's amenities throughout the world.

HARLAND

THE HARLAND ENGINEERING COMPANY LIMITED

ALLOA SCOTLAND *Phone:* ALLOA 390 *London & Export Sales Office:* 20 PARK STREET, LONDON, W.1.

Branches throughout the World

WATER POWER

A technical journal devoted to the study of all aspects of Hydro-electric developments

Annually 40 shillings by post. Single Copies 2s. 6d.

Volume 10 Number 5

CONTENTS FOR MAY, 1958

Editorial: The Next Ten Years - - - 161

Editorial Notes - - - - - - 162

Correspondence: The Bersimis Turbines - - 164
By P. Dériaz

Volga River Development—I - - - - 165
By Engineer G. A. Russo

Economics of Large Modern Surge Tanks - - 172
By Dr. Charles Jaeger

Rotor Handling in Hydro Stations - - - 178
By E. Mean, Ing.A.I.Lg.-A.I.M., J. George, Ing.A.I.Br., and R. Normand, Ing.A.I.Ms.

Some SADE Developments—III - - - 181

Vibration Tests on Weirs and Bottom Gates—IV - 190
By Dr. Ing. K. Petrikat

Short Articles: Salzgitter Bunker Train—Atlas Copco LM Loader—Vinyl Resin Waterstops—Switchgear for Kariba—The Dall Orifice - - - - 198

Abstracts from the World Technical Press - - 201

Editor: H. STOREY, M.C., B.Sc., M.I.M.E.

PUBLISHED BY TOTHILL PRESS LIMITED
33 Tothill Street, Westminster, London, S.W.1
Telegrams: Trazette, Parl. London. Telephone: Whitehall 9233 (20 lines)

MANCHESTER: Century Insurance Building, St. Peter's Square. Telephone: Central 7667/8/9
BIRMINGHAM: 90 Hagley Road, Edgbaston. Telephone: Edgbaston 2466
NEWCASTLE-ON-TYNE: 21 Mosley Street. Telephone: 22239
GLASGOW: 139 Bothwell Street. Telephone: Central 4616
LEEDS: 70 Albion Street. Telephone: 27174
BRISTOL: 8 Upper Berkeley Place, Clifton. Telephone: Bristol 21930

New power for a Dominion from the Roxburgh Hydro-Electric Project

New Zealand's largest hydro-electrical undertaking, the Roxburgh project, will eventually feed an additional 320,000 kilowatts of electricity into the South Island grid system. The 1,200 ft. Dam, which is the largest ever built in the Dominion, was completed far ahead of schedule by Cubitts' New Zealand Co., in association with Conrad Zschokke Ltd., Geneva, and Downer & Co. Ltd., New Zealand.

This is one of many examples where the experience of the Cubitt Group of Companies is helping in the development of overseas territories.

With the experience of the past

CUBITTS

BUILD FOR THE FUTURE

THE CUBITT GROUP OF COMPANIES

Great Britain · Canada

New Zealand · West Indies · Middle East

HOLLAND & HANNEN AND CUBITTS LIMITED · ONE QUEEN ANNE'S GATE · WESTMINSTER SW1

TGA C219

WATER POWER

A technical journal devoted to the study of all aspects of Hydro-Electric Development

The Next Ten Years

EVERY now and then a chill of uncertainty is felt by engineers responsible for forecasting the future demand for electrical power. There are suggestions that saturation point is being approached, and a trade association has reported a levelling-off in the sales of certain key products. In Great Britain it has been suggested that the curtailment of expenditure on the part of the Central Electricity Generating Board is not due only to the financial limitations imposed by the Treasury but also to the cautious reports made by the load forecasters, who no longer believe that the rate of rise of demand is likely to maintain itself at the doubling-in-ten-years figure we have for so long taken for granted. Another straw which might blow in the economic wind is a report from the U.S.A. that the manufacturers of television sets have come to the near-saturation point in regard to the supply of receivers, at least to "single-set homes."

It is not our present purpose to comment on the degree of substance in these forebodings which, in any case, can only be applied to countries where the level of electricity consumption is already high and must remain at least as high if they are to maintain their present standards of living. In the rest of the world—and this is the greater part of the inhabited globe—the level of electrical usage *per capita* is still so far below the rate in industrialised areas that millions of megawatts of new generating plant will be needed to bring them into the same electrical demand bracket.

The purpose of this note is to suggest that we do not need to rely on the chance observations of non-electrical economists to determine our future. Too often has it happed that economists, acting on statistical data from the past extrapolated to the future, told us that it is not feasible to develop this or that project, and, too often, the engineers have over-meekly agreed, with the result that the project has been stifled. To give only one example, the Severn Barrage was economically damned because of the cost of current it could provide compared with that provided from coal at the price reigning at the times the various reports were made. It was always stated that if coal went up by, say, two shillings a ton the Barrage would pay; and then, when coal had gone up by three or four times that amount, civil-engineering costs had also risen, so a new Report once again posed this same apparent dilemma. What none of the economic theoreticians mentioned was the fact that coal is needed for export purposes and therefore its value was not only a matter of domestic price levels but also one of prestige in the export world, the maintenance of export connections, the future of particular pits and their types of coal, and many other considerations not assessable by balance sheets alone.

Had the Severn Barrage been built, say, twenty years ago, Britain would have had an asset which would have saved about a million tons of coal a year; in addition there would have been available a perfect partner for the Berkeley nuclear power plant, now being built a few miles away along the Severn estuary. The 880 MW tidal plant proposed would have meant that the 275 MW nuclear plant at Berkeley could operate at an even more favourable load factor than can be envisaged at present, and without expensive transmission costs. As matters stand, only the French have had the courage to ignore the economic Jeremiahs who prophesied that a tidal-power scheme could never pay, and they have proceeded with the Rance project, gaining international prestige (a most valuable if intangible asset) as well as having a plant which will form an excellent partner for their future nuclear stations.

Nowadays the statisticians have at their disposal electrical computing machines, which mean that their labours can be greatly lightened, or, to make the point in a better way, a given statistical effort can achieve much greater results. The forecasting of load can nowadays be carried out on a much broader basis than in the past. It has long been possible to relate five-year forecasts to probable employment levels, indices of production, changes in population areas, and many other factors, but the results obtained by different statistical approaches differed to a far greater degree than would have been thought probable. In an in-

augural address given by M. G. Kendall to the London School of Economics, delivered in 1950, the speaker said that statistics were the principal means so far yet devised for bringing within grasp the complexities of nature and the relations existing between different phenomena. Until recent years, however, the number of samples, in the statistical sense of the word, that an electricity-supply statistician could employ in his calculations of the future demand was limited by the practical consideration that if he had employed all the data he would have liked to take into account, by the time he had evolved an answer the forecasting period itself would have elapsed. Now, with computers capable of taking in and digesting an almost unlimited number of data in a matter of hours rather than years, this limitation is removed.

All too often the harnessing of hydro-electric projects which are perfectly feasible from the technical point of view has been delayed or abandoned because a chance wind of doubt has blown through a board room or a treasury office. It was decided that the project might not earn its full return on the capital expended, as seen from a narrow, immediate profit-and-loss account taken out on current figures, and so it was ruled out.

In pressing forward with the harnessing of nature's greatest gift to mankind, even greater than that of atomic power because of its simplicity and of its perpetual nature, hydro-electric engineers need to take the long-term view, supported (as they can now be supported) by forecasts which are a hundred times more likely to be accurate than those available in the past.

Progress on the Cávado

THE Annual Report for 1957 of Hidro Eléctrica do Cávado, the organisation responsible for developing the Cávado and its tributaries in the north of Portugal, summarises the important progress that has been made in the construction of Paradela dam, which, it is believed, will be the highest rockfill dam in the world. It is being built in three stages. The first, which was completed in October 1956, enabled the new 54 MW set in Vila Nova power station to operate on a run-of-river basis. The second, to impound a volume of 112 million cu. m. at a level of 727 m., was finished a month ahead of schedule in October 1957, and the final stage, bringing the water level to 742 m. and providing a live storage of 158 million cu. m., was expected to be completed during the first quarter of the present year.

Preparatory work was also put in hand for the Alto Rabagão scheme which will provide interannual head storage for the Cávado system. Access roads have been driven to the site of the outlet portal of the Cávado-Rabagão tunnel and to the Rabagão dam site, a high-voltage line carried to these points to provide construction power, and a start made on transferring camp buildings to the new construction sites. Geological investigations on the dam site were nearly complete, and mechanical tests on the soils and rocks were being conducted by the National Civil Engineering Laboratory.

In conjunction with the Alto Rabagão scheme studies were commenced on the development of the Tâmega basin, but studies of the Homen river had to be deferred. An invitation was accepted to prepare definite schemes for the electrification of S. Miguel Island in the Azores.

The last months of 1956 and January 1957 were unduly dry, and after a break in February 1957, the year under review was characterised by low rainfall. The combined output of the HICA stations and of those of Hidro Eléctrica do Zêzere for 1957, at 1,206 million kWh, was 7 million kWh less than that of the previous year, and for nearly four months the supply had to be supplemented by thermal power to the extent of 212 million kWh. During the year, however, the HICA contribution, at 553 million kWh, was 91 million kWh more than in 1956, a total to which the Paradela development contributed materially.

Ffestiniog Tunnel-Lining Contract

A CONTRACT worth about £400,000 has been placed by the Central Electricity Generating Authority with the Redheugh Iron & Steel Co. Ltd. for supplying the tunnel linings and other pipework for the Blaenau-Ffestiniog pumped-storage scheme in North Wales. The connection between the upper and lower reservoirs is formed by two vertical shafts, 700 ft. in depth, and two horizontal tunnels which will emerge from the hillside above the power station; from this portal there will be four penstocks leading to the four 75 MW pump-generating units.

Hungarian-Yugoslav Electricity Link

A 50-MILE cable linking the electricity supply systems of Hungary and Yugoslavia has now been put into operation. Hungary will tap an estimated 100 million kWh a year via the cable, which runs from Varasd to Söjtör, a few miles inside Yugoslavia. Work on laying the cables began last September. Another cable link between the two countries is to be built from industrial Szeged to Subotica, in Yugoslavia.

British Hydromechanics Report

THE British Hydromechanics Research Association has now been in existence for ten years, and according to its Annual Report the year October 1956 to September 1957 has been the most active since its formation. The laboratory has produced 23 important research publications and dealt with a record number of technical queries. A very successful conference was held, and the Open Days were attended by about 700 visitors.

Following investigations now completed on the Kariba intakes, the laboratory is now engaged in studying various aspects on the Ffestiniog pumped-storage scheme. Four models have been constructed. A 1:30 scale model has been built of the Stwlan reservoir and the two intakes to study conditions causing air-entrainment vortices and to consider possible remedies, and these studies are being supplemented by limited use of a 1:240 scale model to examine vortex phenomena. Reasonable agreement between these two models is found at equal velocities. Flow conditions and head losses are being studied on air models to a scale of 1:14·5 of an intake and upper bend and of a lower bend of bifurcation.

A new method has been developed which will often give a good measure of wall friction forces in hydrau-

lic flow where no other means is available. It is restricted to turbulent two-dimensional flows where the velocity distribution can be measured close to the wall, and depends on the fact that within a certain region the velocity gradient depends only on the wall shear stress and the fluid density.

A step forward in the use of air testing on centrifugal pumps has been made by constructing a dynamometer drive measuring input power within 0·5%. Work continues on the design of suction intakes, and studies are being made on stepped diffusers. Investigations continue on matters relating to hydraulic machinery and on the hydraulic transport of solids.

Calgary Power Extensions

TO supply Alberta's growing power needs Calgary Power Ltd. in 1957 continued its programme of expansion. The Cascade plant extension, 5 miles east of Banff on the Trans-Canada Highway, was completed in September, the plant capacity being doubled, with 23,000 h.p. being added to the company's system. In July 1957 work began on the Rundle and Spray plant extensions; 40,000 h.p. will be added to the Rundle plant and 62,000 h.p. to Spray. These projects will be ready for operation in the autumn of 1960. At the Wabamun steam plant work is completed on the extension which will house a duplicate of the first 88,000 h.p. unit that went into operation in October 1956. A third unit of 200,000 h.p. capacity is scheduled for 1961. The cost of expanding the generating capacity at Cascade, Rundle, Spray and at Wabamun is estimated at some $30,000,000.

During 1957 over 700 miles of transmission and distribution lines have been added to the system. Nearly half of these lines were extensions to serve oil fields, particularly in the Cremona-Sundre–Joffre-Gilby and Pembina fields. Some 800 oil well services were connected in 1957. One of the 138 kV lines between Ghost hydro plant and the East Edmonton substation, just outside Edmonton, is being strengthened by 60 per cent. and a new 69 kV interconnection with the City of Edmonton will replace the former 13·8 kV interconnection.

The industrial load has continued to grow and farm electrification went on apace again this year with some 2,000 farms being electrified. Over 29,000 farms are now being served by the company. The provincial total of farms receiving central-station power will be some 40,000 by the end of 1957.

Further English Electric Order for Priest Rapids

THE English Electric Export & Trading Company has been awarded a further contract for Priest Rapids, and is to supply two water-turbine generating sets, each 83 MVA at 85·7 r.p.m. English Electric is already supplying the first eight turbines and generators and five 183 MVA 13·2/230 kV transformers for Priest Rapids, in conjunction with Merritt-Chapman & Scott who are undertaking the civil work as main contractors.

The Priest Rapids project is one of a chain of stations being built to develop water power along the Columbia River system in the Pacific Northwest. Its site is downstream from Grand Coulee, Chief Joseph and Rock Island dams, but upstream of McNary dam and immediately above the confluence of Snake River with Columbia River. The new dam and power house are an undertaking of Grant County Public Utility District No. 2 of Ephrata, Washington State.

The whole project is under the technical supervision of the Harza Engineering Company of Chicago, Illinois, whose services have been retained by Grant County P.U.D. as consultants. An article on the scheme will appear in this journal shortly.

British Power Exhibits at Brussels

IN the British Industrial Pavilion at the forthcoming Brussels Exhibition great emphasis is being laid on the pioneer work carried out in Great Britain on nuclear power. Special stands have been taken by the Atomic Energy Authority under the auspices of the Board of Trade, and by two industrial combines—the English Electric-Babcock & Wilcox-Taylor Woodrow Atomic Power Group, and The Nuclear Power Plant Company consisting of eight specialist firms.

Nuclear energy will also form the subject of one of the three "Chambers of Energy" on the stand of the British Electrical and Allied Manufacturers' Association, the other two chambers being devoted respectively to thermal power and to water power. In the water-power chamber the centrepiece will be a Kaplan runner about 18 ft. in diameter, and there will be an animated model of a Kaplan-type hydro-electric set and a sectional working model of part of an impulse turbine, besides a diorama of a typical pumped-storage scheme and an extensive display of photographs.

In a comprehensive exhibit of telecommunications and computer equipment, Standard Telephones & Cables Ltd. will refer to their recent contract for telecommunications and remote-control equipment for Kariba.

Karadj Dam, Iran

A CONTRACT to build a concrete arch dam across the Karadj River has been awarded to Morrison-Knudsen International Constructors, Inc. This is an Iran State project and will be situated some 40 miles north east of Tehran, the capital, and will provide both power and water supply. The dam will rise some 590 ft. above the deepest foundation and will have a crest length of 1,264 ft. The power house will be designed to accommodate three 40,000 kW generating units, two of which will be installed under the present contract price of 35 million dollars.

Bulk Supply from Owen Falls to Kenya

THE bulk supply of electricity to Kenya from the Owen Falls hydro-electric power station in Uganda was formally inaugurated recently by the Governors of Uganda and Kenya. The Governor of Uganda, Sir Frederick Crawford, spoke from Owen Falls to the Governor of Kenya, Sir Evelyn Baring, in Nairobi, and the speeches were relayed by carrier current over the 323 mile 132,000 V supply line from Owen Falls to Nairobi.

Sir Frederick said that this ceremony marked the official opening of the 132,000 V link between the two territories and the provision of a bulk supply of electricity from Owen Falls to the Kenya Power Company. The agreement between the Uganda Electricity

Board and the Company was for a supply of electricity up to a maximum of 45,000 kW and he mentioned that the maximum demand supplied to Kenya had already reached 14,000 kW.

Hungary to Dam the Danube

HUNGARY is preparing to build its first hydro-electric station on the Danube at a narrow section just above Nagymaros, where the river emerges from between the Pilis and Korzsony Mountains, near the country's northern frontier with Czechoslovakia. The works will consist of a gravity-section right wing 320 m. long, a power-station section in the centre, and the spillway and locks on the left. The spillway will be controlled by nine gates 30 m. wide and 11·5 m. high. Ten 18,500 h.p. Kaplan turbines will be installed. Double locks will be built, each 230 m. long by 34 m. wide and capable of accommodating six 1,000 ton barges.

Building the dam will raise the water level some 6 km. and will create a backwater nearly 100 km. long, and dykes will have to be built as far as Komarom to prevent flooding.

Currents and the effects of flooding and ice flow have been studied in detail by the Hungarian Building Industry Technical University. More than 700 drillings have been made up-river, and three floating drills have made about 60 drillings into the river bed. Information has also been made available from the German and Austrian Danube power stations at Jochenstein and Ybbs-Persenbeug.

This development will form part of a broader scheme to exploit the Danube from the River Morva on the Czech-Austrian frontier down to the Black Sea, and involving irrigation, flood defences and navigation as well as power production. Two other power plants are envisaged, one on the Czech-Austrian frontier near the Austrian village of Wolssthal, and the other at the Iron Gate rapids on the Rumanian-Yugoslav frontier.

Electricity Supply in Victoria

THE 38th Annual Report, for the year ended June 30, 1957, of the State Electricity Commission of Victoria, Australia, records satisfactory progress in both financial and technical aspects. Electricity sales increased by 7% (254 million kWh), generating capacity was increased by 175,550 kW, and the maximum demand on the system for the first time exceeded one million kW. The Commission supplied 99% of the electricity used in the State.

The power economy of Victoria, of course, is based primarily on the indigenous supplies of brown coal, but hydro power plays an integral and increasing part in the pattern of generation. Reference is made in the Report to the completion of the 120 MW station at Eildon, and to the operation of Kiewa No. 4 Development, of 61·6 MW capacity, since April 1956. In connection with the latter, a tunnel to divert water from the West Kiewa River to No. 4 station, was brought into service in June 1957, which would increase the output by about 50%. For the Kiewa No. 1 (Upper) 96 MW Development the headrace tunnel had been completed, work was proceeding on the pipeline the upper section of the tailrace tunnel had been excavated for its full length, and excavation of the underground power station commenced. Work had continued on the placing of rock and earth fill at Rocky Valley dam and on the cut-off wall.

An important section of the Report is devoted to a summary of the main provisions of the agreement, already referred to in this journal, signed between the Governments of the Commonwealth, Victoria, and New South Wales, covering participation in the use of power from Snowy Mountains. Power provided by this scheme will be essentially of low load factor (24% for the completed scheme) and will need to operate in conjunction with thermal base-load plant of about 80% load factor to satisfy a total system load factor of 55—60%. By 1965 it is expected that Victoria will be able to draw upon 200 MW of low load-factor power from the Snowy scheme, and this should rise to 900 MW when the scheme is completed in 1982-3.

Summer Meeting on Cavitation Mechanics

THE Massachusetts Institute of Technology are staging a special summer programme to discuss the importance of cavitation in hydraulic devices. In making this announcement, they state that new applications, as well as more stringent performance requirements in old applications, continue to call for improved and novel designs to eliminate or minimise cavitation. The programme covers a comprehensive survey of the fundamentals of the cavitation process, including its initial occurrence and its mode of development in various different flow situations; discussions of the effects of cavitation on the hydro-dynamic behaviour and performance of hydraulic machines and hydraulic structures, methods of predicting cavitation, and methods of control; and a study of cavitation damage and how it occurs, methods of damage testing, and the resistance of materials to damage. In addition, there will be miscellaneous topics which do not fall explicitly within these categories.

Correspondence

Bersimis Turbines

To the Editor of WATER POWER,

In the article "Hydro-Electric Progress in Canada, 1957" in your March issue there is an inaccuracy in the rating of the Bersimis I Francis turbines. The rating of 150,000 h.p. should refer to the low head of 785 ft. Under the maximum head of 875 ft. the rating is 175,000 h.p.

The installation of four such machines manufactured by The English Electric Company was completed in 1957. These machines were designed for a maximum output of 200,000 h.p. and have produced this output in service. These units, built in Canada to design produced in this country, are to date the most powerful water turbines in operation in the world. The achievement of a world record by British engineering will certainly be of interest to many of your readers.

P. DERIAZ,
Chief Designer, Water Turbine Department,
The English Electric Co. Ltd

Fig. 1. Power-house block in course of construction during spring flood

Volga River Development

Brief particulars are given of the scope of this development scheme with special reference to the Kuibyshev Power Station

By ENGINEER G. A. RUSSO

PART ONE

THE VOLGA, the greatest river in Europe, has a length of 3,690 km. from its source on the Valdai Plateau to its mouth at Astrakhan on the Caspian Sea; the fall is 256 m. For the most part the flow is derived from the thaw of snow in the spring and is affected only to a minor extent by precipitation and ground water. Consequently the flow is characterised by protracted and high spring floods, a fairly constant low-level discharge—augmented to some degree by autumn rains—and a minimum flow in the winter frost. The mean yearly rate of discharge of the Volga is 2,870 cu. m. per sec. at Gorki, rising to 7,680 at Kuibyshev, and 8,130 cu. m. per sec. at Stalingrad.

The full development of the Volga is planned to take the form of a series of 13 hydro-electric plants, as shown in Fig. 2, having a total capacity of 8·3 million kW and producing 40,800 million kWh in an average hydrological year. At the present moment, the Ivankov, Uglitsh, Shcherbakov, Gorki and Kuibyshev power stations are in operation, and Stalingrad and Saratov are in course of construction. Cheboksar, between Gorki and the confluence of the Volga and the Kama, is earmarked for construction within the Sixth Five-Year plan, thus leaving four smaller stations upstream of Ivankov on the upper Volga, and a station on the Lower Volga, roughly halfway between the Stalingrad bend and Astrakhan, to be undertaken later.

The Kuibyshev station, the largest of the whole series, stands practically at the extremity of the Samara loop, a U-shaped bend, 200 km. long, which cuts across a massif of Carboniferous and Permian limestone and dolomite.

At first the dam was projected to stand about 20 km. upstream from the city of Kuibyshev, at a point where a rock bed had been found on both banks of the river and of sufficient area to carry the spillway block of the dam, the power house itself and the navigational locks. This rock was overlain by a thick deposit of alluvium. In the river bed itself, however, the rock was found to have been scoured out during the Tertiary era to form a gorge more than 200 m. deep. In addition to the power house planned to be built across the river bed, a second power house was projected at the end of the diversion canal which was intended to bypass the Samara loop. Comprehensive exploration work established, however, that the calcifero-dolomitic rock which formed both banks of the Samara loop was greatly dislocated, and was further intersected by Karstic faults to a depth of 200 m. below the present water level of the river. The geological conditions in the line to be followed

by the contemplated diversion canal also left a great deal to be desired.

Obviously the construction of a concrete dam, two power houses, a diversion canal, and navigational locks, on such an unsatisfactory foundation would have entailed extensive excavation work, not to mention the construction of an impervious curtain against infiltration, and the cost of dewatering the foundation pits while the work was in progress. The extra expenditure involved was estimated to amount to about 17% of the total cost.

Eventually it was decided to site the works on sandy-clayey ground on the upstream limb of the Samara bend. The site chosen for the right-bank structures was situated at a point where a large pothole had been scoured out of the rock to a depth of over 200 m. The pothole filling consists of Neogene clay and Quarternary sand-clay alluvium, and projects from the right bank of the river to form a natural spur which ensured a reliable and convenient protection against water infiltration into the construction pit. On the left bank the foundations consisted of alluvial sandy deposits 70 to 80 m. thick. In the river bed itself the deposit consisted in part of clayey

Fig. 2. Volga basin showing power stations in operation, under construction and projected

deposits of the same nature as those filling the pothole on the right bank, and in part of recent sand-clay alluvium (Figs. 3 and 4).

The decision to raise the water level 28 m. above the mean stream level was governed mainly by the extent to which it was desirable to limit the flooded area. Extensive work will need to be carried out, for example, to protect the city of Kazan from flooding. It is intended that the backwater of the Kuibyshev power station will reach upstream as far as the future Cheboksar plant on the Volga itself, and as far as the station projected on the Lower Kama.

Measured over a period of many years, the mean annual discharge of the Volga at the site of the Kuibyshev power station is 241 cu. km., which corresponds to a mean rate of discharge of 6·3 lit. per sec. per sq. km. The lowest discharge, 145 cu. km., occurred in 1921, and the highest, 366 cu. km., in 1926. The major part of the yearly discharge, about 64%, flows at the time of the spring floods, and the flow sinks to a minimum when the river freezes in the autumn; for instance, in November, 1944, the rate of flow was no more than 813 cu. m. per sec.

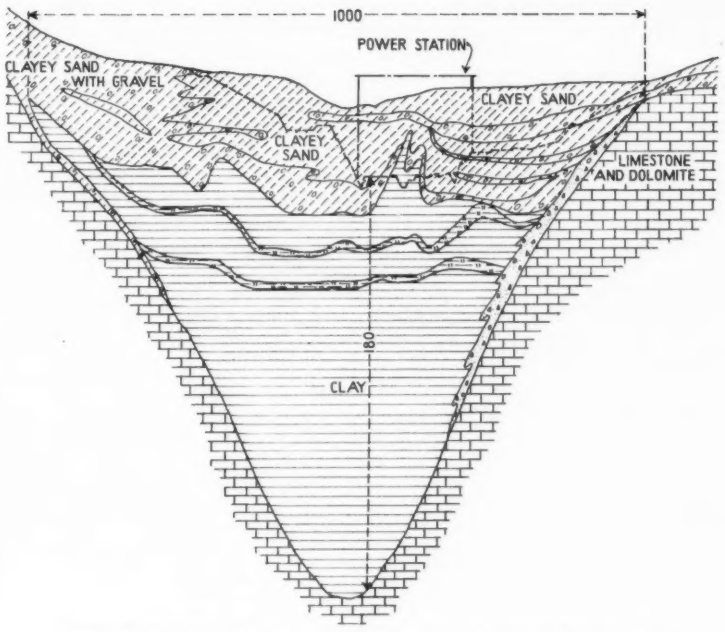


Fig. 3. Section through ancient gorge at power-house site

The reservoir created by the Kuibyshev works will cover an area of 5,580 sq. km., and have a capacity of 52·3 cu. km.; its purpose is to ensure seasonal regulation of the flow. The maximum useful storage head will be lowered later, as the new power stations on the Volga and Kama are put into commission.

During the initial period, when all existing plants and those under construction are in operation, the storage head will reach 7·5 m., corresponding to a useful capacity of 31·5 cu. km. The rated capacity of the power house at Kuibyshev is 2·1 million kW. The length of the Kuibyshev dam is 4·5 km. During the first stage the production in an average hydrological year will reach 10,800 million kWh. As the flow of the river will be regulated to a considerable extent the coefficient of utilisation will be no less than 0·86 to 0·92. The Kuibyshev power station is designed to operate on the basis of semi-peak load in the initial stage, as the regulation of the flow will be restricted by releases of water for navigation purposes. It is now supplying energy to central Russia and the Volga basin through a network of 400 kV transmission lines. An additional line, now in course of erection between Kuibyshev and Moscow is designed to operate at 500 kV.

The layout of Kuibyshev, as shown in Fig. 5, was planned with a view to enabling the largest volume of water to pass through the power house as early as possible. The power house block has been intentionally erected near the right bank on firm clayey ground which is not so easily scoured as the sand on the left bank. To reduce the extent of the earthwork entailed by the head and tail races, it was decided to build the spillway block on the left bank, where it was also possible to utilise an existing arm of the Volga.

Along the left bank of the river there are several lakes and old river channels, and their utilisation reduced to a certain extent the amount of work required for the construction of navigation facilities. This presence also explains why the locks are built

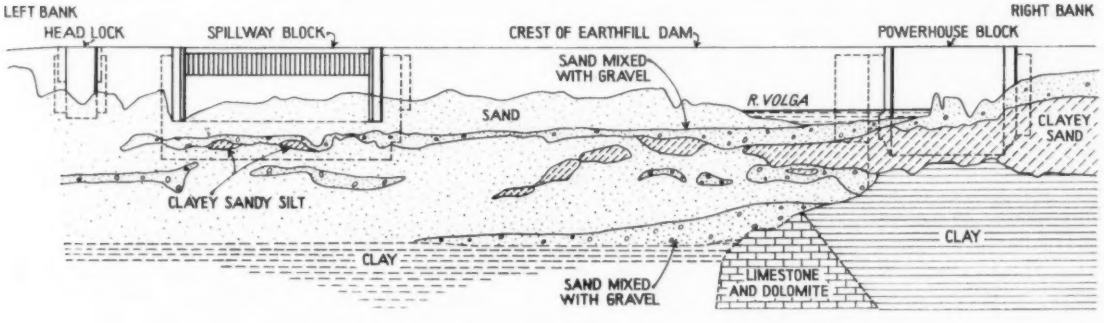


Fig. 4. Geological section through axis of Kuibyshev works on Volga

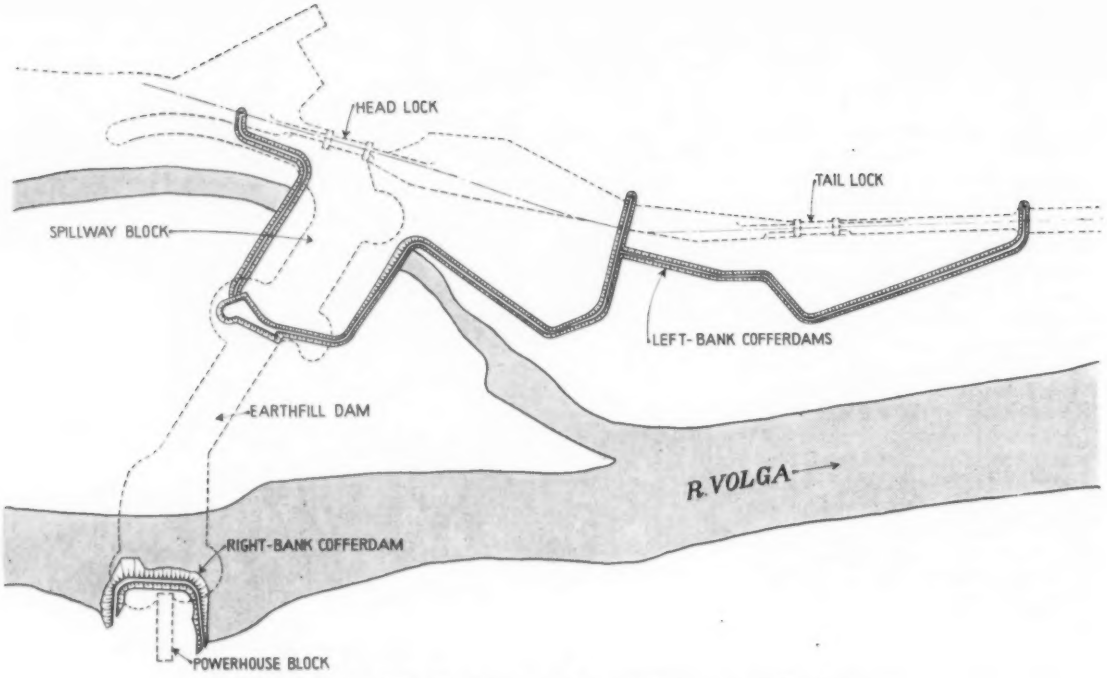


Fig. 5. Plan of Kuibyshev site showing layout of cofferdams

on the left bank. The general picture of the Kuibyshev works, considered as a whole, is that of two wings of concrete structures connected across the major bed of the river by an earth and rockfill dam.

The generating equipment of the Kuibyshev power station consists of twenty 105 MW vertical generating sets, each driven by a Kaplan turbine 9·3 m. in diameter. The diameter of the stator is 14·3 m., and including the cooling system, 20 m. The generators are designed for 13·8 kV and a speed of 68·2 r.p.m. The turbines operate on a normal head of 19 m. and have a discharge capacity of 675 cu. m. per sec. An unusual feature of the generating sets is that the thrust bearing is placed on the cover of the turbine.

For local consumers there are 220 and 110 kV transmission systems in which the cables are laid in steel pipes filled with oil under pressure. The 400 kV distribution system connects with the power house by means of an overhead line.

The generating sets are started, stopped and controlled automatically. The power house is operated from a central control desk, and provision has also been made for remote control from the dispatcher room of the unified grid system serving the European parts of the U.S.S.R.

Fig. 6 shows a vertical cross-section through the power house and Fig. 7 a plan and longitudinal section.

A comparative investigation of the costs between the alternatives of constructing a power house and an earthfill dam, and the normal type of power house combined with a spillway block provided with an appropriate number of sluice gates, proved that the former was more economical.

The intakes at the face of the power-house block are equipped with trashracks and consists of screens mounted between concrete pillars. These pillars support a railway track on which the collected trash is removed by trucks. Stoplogs are provided to seal off any screen needing repair. The efficiency of this design of trashracks had already been established in connection with the operation of other power stations where debris and turf caused the efficiency of the generating sets to be affected and even entailed temporary stoppages.

The discharge of the Volga at the time of a flood with a 0·1% factor of probability was assessed at 67,000 cu. m. per sec.; when passing such a flood, the rise of the water level does not exceed the normal rise at the dam. When discharging this quantity, 28,000 cu. m. per sec. pass the power house and 39,000 cu. m. per sec. through the spillway block.

The possible discharge in the case of a flood with a 0·01% probability factor is estimated at 83,700 cu. m. per sec., and the rise of the reservoir level is assessed at 2·3 m.

The spillway block is built on fine sand intermingled with thin layers and lenticular blocks of clay and sandy clay; it consists of thirty-eight 20 m. openings. Construction joints running through the concrete pillars divide the structure into 19 sections.

After the release of the 1956 spring flood a third groove was cut into the spillway piers for the insertion of sluice gates in order to enable work on the spillway block to be completed. It will eventually be possible to use these grooves for emergency gates should it become necessary to set up a protective breakwater. From experience gained at other dams, it is known that between the beginning of frosty weather and the freezing of the water in the reservoir, high waves may cause ice to adhere in fairly thick layers to the gates, or even to the crane tracks laid on the top of the

spillway. The provision of a breakwater which will prevent these high waves from beating against the gates is therefore desirable.

The mean rate of overflow discharge at the Kuibyshev spillway was laid down at 40 cu. m. per sec. for every metre of length of the overflow crest at periods of average flood, and 56 cu. m. in the case of high floods. To protect the structure from being undermined, the toe of the foundation apron is laid 15 m. deeper than the river bed, and a layer of riprap 3 m. thick covers the curved end of the bucket leading to the stilling pool. The depth and size of the stilling pool were determined by computation and by model tests, with a view to ensuring that the flow of the calculated flood discharge would not exceed a velocity likely to cause scouring.

When determining the depth of the stilling pool, the coefficient of variation in discharge along the dam introduced into the calculation was 1·3. This coefficient was adopted on the basis of a number of tests conducted on models of various spillway dams, including that of the Kuibyshev design.

The discharge of flood water at Kuibyshev is scheduled as follows: flows up to 10,000 and 13,000 cu. m. per sec. can be passed through the turbines; in the case of greater floods the gates of the spillway block are opened to a height of 2 m., at which ice blocks are not sucked down by the current. The aggregate discharge passing both power house and spillway is then 24,500 cu. m. per sec. The next operation is gradually to open the emergency outlets of the power house, which can cope with a discharge of up to 22,000 cu. m. per sec., followed by the opening of the spillway gates up to 4 m., if there is no breaking up of the ice. Finally, the spillway gates are opened, in sequence, to the full extent.

This operating procedure offers the great advantage of enabling the level of the water at the spillway to be raised gradually; even so it is necessary to reinforce the watertight apron in front of the spillway to prevent undermining from upstream. The possibility of this had to be taken into consideration, as the average velocity of the flow at the non-reinforced apron reaches 2·1 m. per sec. when releasing the discharge on which the calculations were based.

The heights of the overflow sill of the spillway and of the breakwater, and the extent to which the apron had to be carried upstream and downstream, were determined by means of model tests. Characteristic results are shown in Fig. 8.

To ensure greater stability, the aprons of the power house and spillway blocks have been designed to form one piece with their main structures. This procedure of pouring the protecting apron solid with the work to be protected has been applied at numerous dams in the U.S.S.R. and has thoroughly proved itself. when determining the design of the dam with a view to ensuring the best protection against seepage, full consideration was given to the need of reducing the counterpressure on the overflow section and to securing seepage gradients corresponding to the permeability and cohesion of the fill materials.

In the foundation strata, at a depth of 10 m., a layer of sand occurred having a seepage coefficient six to ten times greater than in the upper layers. Also there were numerous lenticles and intermediate layers

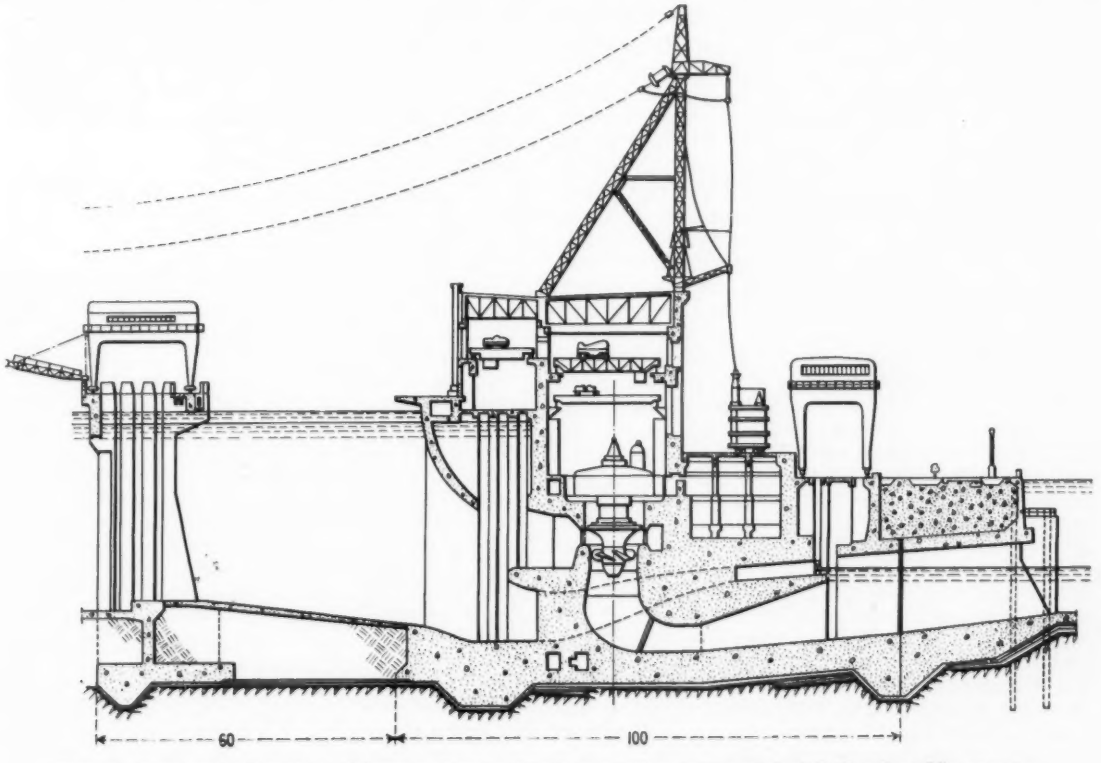


Fig. 6. Sectional elevation of power house showing service crane and right-bank cable crane

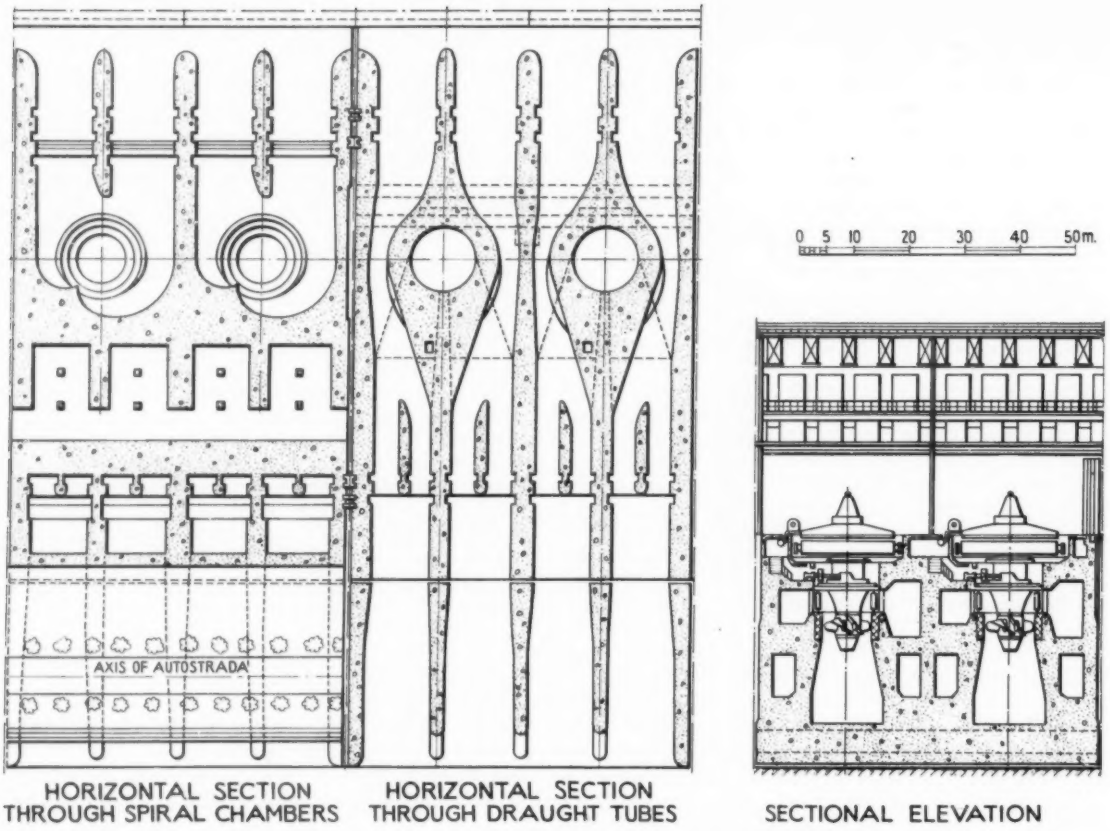

AXIS OF AUTOSTRADA
0 5 10 20 30 40 50m.
HORIZONTAL SECTION THROUGH SPIRAL CHAMBERS
HORIZONTAL SECTION THROUGH DRAUGHT TUBES
SECTIONAL ELEVATION

Fig. 7. Plan and sections of two bays of power house

of argillaceous sand and clay. To prevent percolation, a curtain of steel piles was sunk 21 m. deep in front of the apron at the upstream face of the spillway. In addition drainage layers were set up under the stilling pool. This sheet piling is driven through a highly impermeable layer. To reduce seepage from the pools formed by the first and second row of baffles, and also to prevent ice from adhering to the slabs at low-water periods in winter, a sheet-pile curtain is sunk to a depth of 9 m. at the toe of the second row of baffles.

When determining the basic measurements of the power-house and spillway blocks, the following conditions were assumed in the stability analysis:—

Spillway: the full calculated discharge passing over the structure, and shearing stress occurring through the plane of the largest mass of cohesive soil;

Power house: normal water level upstream, minimum water level downstream, and plane of rupture passing through the weakest layer of clay present in the foundation ground. Due consideration was also given to the possibility of plastic deformation of the foundations after a long period of service, and this led to investigating the stability of the power-house block at the point of the thinnest layer of clay. Special care was taken with the static computations for the longitudinal and transverse cross-sections of the dam. With regard to the latter, a portion of the dam in the direction of the flow of the river was assumed as being a buttressed wall, the buttresses being formed by piers solidly connected with the wall. In the case of the longitudinal section the foundation slab was considered as a slab resting on an elastic floor and having to support the weight of the overflow water and of the piers. The edges of the foundation slab were considered as following closely the outline of the ground and grouted on three sides. In addition, each individual element of the dam was calculated on the basis of local loads.

The power-house building was also calculated both as a whole and for local loading. Each individual portion of the building was treated as a separate solid structure. The behaviour of concrete for all submerged sections of the works was carefully investigated with a view to avoiding cracking. Reinforcement steel was selected on the basis of destruction tests. In view of the large volume of reinforcement involved, bars of best-quality steel up to 90 mm. in diameter were used.

The Kuibyshev station also incorporates works to facilitate navigation; these include an upstream dyke about 2 km. in length with a 650 m. breakwater, the Stavropol harbour, a one-stage head lock with two parallel chambers, a 3·8 km. canal between the head and tail locks, a tail lock and a downstream canal 7 km. in length.

The navigation locks are built on sandy ground interspersed with lenses and layers of soft ancient clay. At certain places beneath the foundations of the lock chambers, it was necessary to substitute sand for some of these clay lenses, which reached 4 to 5 m.

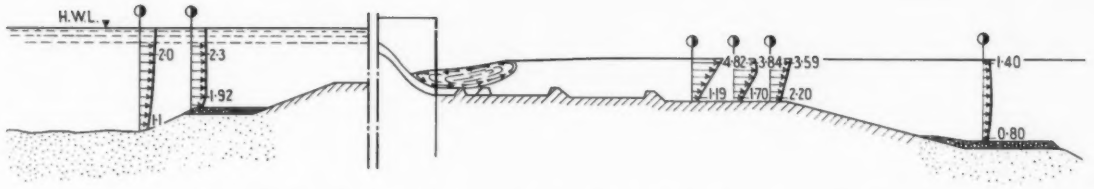


Fig. 8. Distribution of computed flood velocities shown graphically

in thickness. The choice of two one-stage locks was dictated by the necessity of maintaining navigation during the constructional period and when the water level was below normal; the canal connecting the two locks was provided with a suitable bypass. The large workshop erected on the harbour embankment for the maintenance of the constructional equipment will be subsequently used for ship repairs.

Water is admitted to the lock chambers by means of three longitudinal bottom inlets fitted with a series of orifices. This enables the lock chamber to be filled in eight minutes and to restrict the longitudinal stress on the mooring ropes of the ships in transit to less than 1 : 3,000 or 1 : 1,500 of the ship's displacement.

The lock chambers are built of reinforced concrete; both head and tail lock crowns are of dock-type design, and an expansion joint runs through the middle of each chamber. The inlet conduits on the floors of the lock chambers are protected by girders of reinforced concrete, trough shaped in cross section. The lock gates are all of the two-wing type.

The plate gates for the inlet conduits of the locks move on rollers and are fitted with watertight packing at their downstream end. These gates and all the other machinery for the locks are operated either by remote control from the central control desk, or by hand on the spot.

The earthfill dam, flanked on one side by the power house and on the other by the spillway block, has a length of 2·8 km.; its maximum height reaches 50 m. in the river bed and 29 m. in the inundation area. A shorter earthfill dam, 420 m. in length and 37 m. maximum height, is inserted between the spillway block and the navigation locks. The fill material of the dam, fine sand obtainable on the spot, was placed by flushing.

In cross-section the earthfill dam has the shape of a flattened trapezoid, with the upstream face sloping 1:4 to 1:15, and the downstream face 1:3 to 1:9. The crest of the dam is broad enough to accommodate two railway tracks, a roadway and two 400 kV overhead lines.

The upstream face, from the crest down to a line 3 m., below the lowest level of the upper water, is protected from surges by reinforced-concrete slabs measuring $10 \times 10 \times 0{\cdot}6$ m. the joints between them resting on a triple layer of drainage strips. The downstream slope is strengthened by a layer of random rubble 1 m. thick. This strong reinforcement of the dam slopes is imperative as the waves may reach a height of up to 3·5 m. Meteorological investigations have proved that wind in the reservoir area may reach speeds of up to 40 m. per sec., and that wave surges may start at points as far as 30 km. upstream of the dam.

(To be continued)

BEAMA Brussels Brochure. In preparation for the Brussels Exhibition the British Electrical and Allied Manufacturers' Association has produced a souvenir brochure, entitled "Serving the World," to publicise the achievements of the British electrical and allied industry in supplying the needs of the world's markets. To do justice to the vast scope of interests represented by this industry would require a library, and to have covered the field so adequately within the confines of a single brochure is no mean achievement.

In an introductory chapter, after a reference to British electrical pioneers of the past, the text leads naturally forward to Britain's pioneer work in the development of nuclear energy for peaceful purposes, and passes to the first main section, "Energy in Harness," where thermal, hydro-electric and nuclear generation are considered in separate chapters. Switchgear, transformers, transmission lines and cables are touched upon in the next section, "Links of Power," after which an important section, "Serving Mankind," devotes individual chapters to electric traction, telecommunications, electronics, industry, radio and television, and lighting and domestic applications. A final section is entitled "Looking Ahead," and includes photographs of "Zeta," the largest impulse generator in Europe, the radio star interferometer aerial at Cambridge, and the radio telescope at Jodrell Bank. A sketch map inside the back cover shows that over the four years 1954-1957, £1,000 million of British electrical equipment was sent overseas.

Of the 50,000 copies of this brochure that have been printed, about half are being sent overseas, together with a leaflet in six languages, and the remainder will be distributed to interested visitors to the BEAMA stand in the British Industrial Pavilion at Brussels. A few copies are available for sale in Britain at 5s. each, plus 1s. postage.

Anchor Stressing of Dams. A preview of a 16 Kodachrome film produced by The Cementation Co. Ltd., in association with the Cementation Company (Africa) Ltd., illustrates the method adopted to heighten the Steenbras dam, about 40 miles from Capetown. This dam is a solid gravity structure, having two straight arms each about 400 ft. long, joined by a curved central portion. It was decided to raise the height 6 ft. 6 in. in order to increase the capacity, and the anchor-stressing method was adopted, Mons. André Coyne being called in to carry out the basic design. A brochure issued by The Cementation Co. Ltd. gives illustrated particulars, and refers to other instances where they heightened dams in this way.

Economics of Large Modern Surge Tanks

By DR. CHARLES JAEGER

THE great number of scientific papers dealing with surge tanks, published in the last twenty years, are an indication of the growing importance they are assuming in modern hydro-electric schemes. Their magnitude is best shown in Table I, where the volume of some modern examples excavated in rock are compared with the excavation required for large underground power houses.[1, 2]

This table shows that the excavation V_S required for a large surge tank often compares with the volume of excavation of the corresponding power house (V_P). The ratio V_S/V_P obviously depends on the head. It is low for high-head stations like Innertkirchen and influenced by the type of industry using the power (i.e. Kemano is for aluminium production only). For low-head stations like Lavey it reaches high values (V_S/V_P=0·84).

The cost of surge tanks like Bersimis or Chute des Passes may be as high as $2,000,000 to $3,000,000.

It is of great interest to analyse the factors which influence the volume V_S and therefore the economics of surge tanks, this being all the more so because such an investigation has not hitherto been attempted. A first approach could be on a statistical basis, a method of real interest if the tabulated figures for actual surge tanks are compared with some others obtained by a purely theoretical approach.

Theoretical formulae for estimating volume

There are two main criteria for choosing the dimensions of a surge tank. It can be dimensioned to produce a positive basic surge or swing Z_* which does not exceed λH_0 where H_0 is the net head, and λ a percentage figure which the turbine designer would like to keep low and is often chosen between 10 and 15 per cent. The surge $Z_* = V_0\sqrt{\frac{L}{g}\frac{A_T}{A_S}}$ is that caused in a system by instantaneous closure of the full discharge Q_0, friction losses being neglected.

L=Tunnel length.

A_T=Tunnel cross section.

A_S=Surge tanks horizontal area.

$v_0 = Q_0 A_T$=Steady water velocity in the tunnel.

The other approach is by calculating the so-called "Thoma area A_{Th}" for surge tank stability and choosing a convenient safety factor, n, so that

$$A_S = nA_{Th}$$

These two different approaches will yield two theoretical values for the surge-tank volume. Comparing these two values with the volume of actual surge tanks leads to a better insight into the problems concerned with the economics of surge tanks.

TABLE I. VOLUME OF ROCK EXCAVATION REQUIRED FOR LARGE SURGE TANKS COMPARED WITH VOLUME OF UNDERGROUND POWER HOUSES

Surge tank	Country	Volume of surge-tank excavation V_S		Volume of under ground power house V_P cu. yd.	$\frac{V_S}{V_P}$	Remarks
		m³	cu. yd.			
(Old) Dixence ..	Switzerland	2,843	3,710	—	—	—
Loch Sloy ..	Scotland	8,900	11,600	—	—	—
Malgovert ..	France	12,180	15,900	—	—	—
Innertkirchen ..	Switzerland	4,140	5,400	59,000	0·092	—
Kemano	Canada B.C.	7,800 15,600	10,179 20,358	277,900 473,000	0·036 0·043	1st stage 2nd stage
Verbano	Switzerland	8,800	11,400	33,000	0·345	—
Isère—Arc	France	17,810	23,200	68,000	0·344	—
Lavey	Switzerland	34,900	45,600	54,500	0·84	—
Bersimis Lac Cassé	Canada (Quebec)	55,700	72,800	54,300 100,500	1·34 0·72	1st stage 2nd stage
Chute des Passes ..	Canada (Quebec)	78,000	101,700	137,800	0·74	Up stream tank only

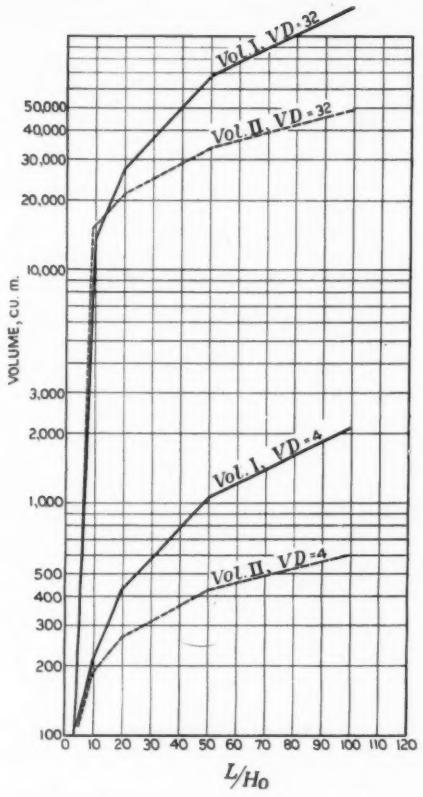


Fig. 1. Curves of surge-tank volume

The first condition can be written

$$Z_* = V_0\sqrt{\frac{L}{g}\frac{A_T}{A_S}} = \lambda H_0 \qquad ...(1)$$

The positive maximum surge Z_{max} is usually smaller than Z_* whereas the negative downswing Z_{min} is usually larger than Z_*. If a surge tank has been calculated for total instantaneous opening and total instantaneous closure of the same steady discharge $Q_0 = v_0 A_T$, then the total volume Vol_I of the surge tank is approximately given by

$$\text{Vol}_\text{I} \cong 2Z_* A_S = 2v_0 A_S\sqrt{\frac{L}{g}\frac{A_T}{A_S}} = 2A_S\lambda H_0$$

But condition (1) yields

$$A_S = \frac{v_0^2}{\lambda^2 H_0^2}\frac{L}{g}A_T,$$

where $A_T = \pi D^2/4$,

or $$\text{Vol}_\text{I} = 2\lambda\frac{H_0 v_0^2}{\lambda^2 H_0^2}\frac{L}{g}A_T = \frac{\pi}{2g\lambda}\frac{L}{H_0}v_0^2 D^2 \qquad ...(2)$$

Assuming for λ the conservative value $\lambda = 0{\cdot}12$, then

$$\text{Vol}_\text{I} \doteq 1{\cdot}34\, L/H_0(v_0 D)^2 \qquad ...(3)$$

Let us now take L/H_0 as the main independent variable and calculate Vol_I, which can then be plotted against L/H_0 as abscissa (Fig. 1). Extreme values for v_0 and D are $v_0 = 2$ m/sec (6·5 ft/sec) and $D = 2$ m (6·5 ft), and $v_0 = 4$ m/sec (13 ft/sec) and $D = 8$ m (26·2ft).

Two curves Vol_I have been traced on Fig. 1 for these two groups of values with $\lambda = 0{\cdot}12$. In Table II a summary is given of some values of Vol_I, that is,

TABLE II

L/H_0	Vol_I	
	$v_0 D = 4$	$v_0 D = 32$
10	214	13,750
210	428	27,500
50	1,070	68,700
100	2,140	137,500

Vol_I for $v_0 D = 4$ and $v_0 D = 32$ and varying values of L/H_0.

As will be seen in Fig. 2 most of the actual surge tanks are inside these two curves. It is also apparent that the ratio L/H_0 and the product VD are the two main parameters on which surge-tank volumes depend.

The other approach consists in comparing the surge tank area with the " Thoma area " for stable oscillations.

$$A_{Th} = \frac{V_0^2}{2g}\frac{LA_T}{H_0 F v_0^2} \qquad ...(4)$$

where Fv_0^2 = friction losses in the tunnel. When writing $$A_S = nA_{Th} \qquad ...(5)$$

and $$Z_* = v_0\sqrt{\frac{L}{g}\frac{A_T}{nA_{Th}}}$$

then $$\text{Vol}_\text{II} = 2A_S Z_* = 2v_0\sqrt{n\frac{L}{g}A_T A_{Th}}$$

The formula of Mannings-Strickler for friction losses is known to be:

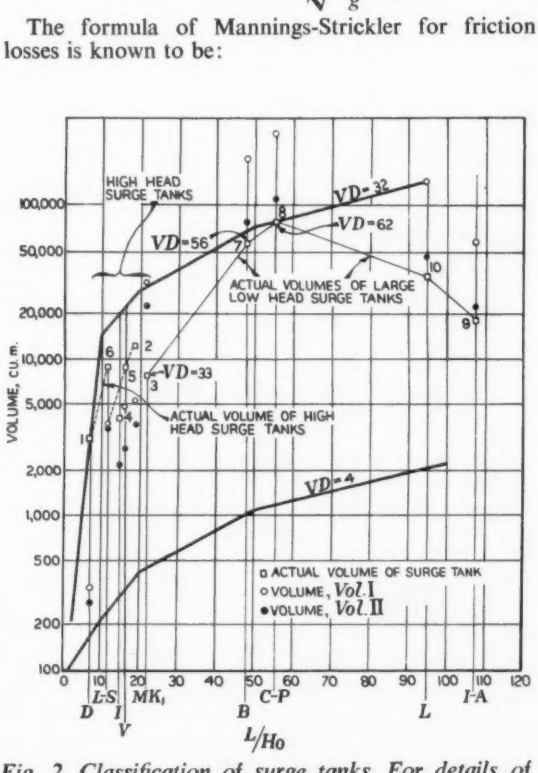


Fig. 2. Classification of surge tanks. For details of surge tanks 1–10, see Tables IV and V

TABLE III

L/H	$\mathrm{Vol_{II}}$	
	$v_0=2,\ D=2$	$v_0=4,\ D=8$
10	193	15,500
20	270	21,800
50	429	34,500
100	610	49,000

SJ

$$Fv_0^2=\frac{(4)^{4/3}v_0^2L}{k^2D^{4/3}}$$

Replacing A_{Th} and Fv_0^2 in the formula for $\mathrm{Vol_{II}}$ yields:

$$\mathrm{Vol_{II}}=2v_0\frac{\pi D^2}{4}\sqrt{\frac{L}{H_0}}\frac{D^{2/3}}{2^{4/3}}\frac{k\sqrt{n}}{g\sqrt{2}}$$

$$=\frac{\pi}{g}\frac{k\sqrt{n}}{7{\cdot}13}v_0\sqrt{\frac{L}{H_0}}D^{8/3} \qquad ...(6)$$

The values $\mathrm{Vol_{II}}$ can be traced on the same diagram Fig. 1 where the values $\mathrm{Vol_I}$ are already shown against the abscissa L/H. For $k=82$ (metric system) and $n=1{\cdot}7$ ($\sqrt{n}=1{\cdot}3$) formula (6) becomes:

$$\mathrm{Vol_{II}}=4{\cdot}78v_0D^{8/3}\sqrt{L/H_0} \qquad ...(7)$$

Table III gives some figures for $v_0=2$ m/sec, $D=2$ m and $v_0=4$ m/sec, $D=8$ m and L/H_0 as independent variable.

These values helped to trace the curves $\mathrm{Vol_{II}}$ in Fig. 1.

The value of the friction factor k is dictated by the roughness of the tunnel walls. For an unlined tunnel, a value of $k=25$ to 35 (metric) is recommended and for lined tunnels $k=82$ to 85 (metric); or exceptionally $k=90$ for very large smooth tunnels. It may be argued that the values of $\lambda=0{\cdot}12$ and $n=1{\cdot}7$ are somewhat arbitrary and that a different estimate would have yielded different curves for $\mathrm{Vol_I}$ and $\mathrm{Vol_{II}}$ in Fig. 1 and given a different picture of the problem. Nevertheless these are more or less accepted figures and they will help the general discussion.

The remainder of this article will cover three main points:

(1) Statistical inquiry into existing surge tanks and comparison of the actual volumes with the theoretical values given by the formula (3) and (7) for $\lambda=0{\cdot}12$ and $n=1{\cdot}7$.

(2) Inquiry into methods used to reduce the volume of surge tanks with regard to formula (3) or (7).

(3) Analysis of the safety factor values to be introduced in formulae (6) and (7) for stable oscillations.

Statistical inquiry on existing surge tanks. There is no need to include a great number of surge tanks in this inquiry. The choice has fallen on a few tanks which may be regarded as being typical. The results of this inquiry are tabulated in Tables IV and V.

The two formulae (3) and (7) for the volumes of surge tanks are the nearest to what can be called "theoretical values for normal surge tanks." Nevertheless it appears that with very few exceptions the actual volume is either much larger or much smaller than the values obtained by simple theoretical reasoning. This proves, a fact well known by designers, that every surge tank is a problem requiring careful study on its own merits and is not one to be solved by rough rule-of-thumb methods.

Both Tables IV and V show that a surge tank with a head of about 200 m. (Loch Sloy, $H_{min}=220$ and $v_0D=15{\cdot}4$) is a boundary case for which we roughly have (see Fig. 2)

$$\mathrm{Vol.}=\mathrm{Vol_I}$$

and $$\frac{Y}{H_{min}}\cong 2\lambda=0{\cdot}24\ (Y=\text{ surge-tank heigtt}$$

It is obvious from Fig. 2 that in instances where $H_{min}>200$ m the total height of the surge tank is not dictated by the turbine designer. In fact, for the surge tanks Nos. 1 to No. 5, $Y/H_{min}<2\lambda=0{\cdot}24$. In all these cases the surge tank height is chosen in order to keep the pressure on the pressure tunnel below a maximum value considered by the tunnel experts to be the limit for safe design. It will be seen that Y is always smaller than 100 m, a value considered to be the limit for ordinary rock conditions.

This leads necessarily to actual surge tank volumes in excess, sometimes vastly in excess, of the theoretical values $\mathrm{Vol_I}$ or $\mathrm{Vol_{II}}$.

In addition, most of these high-head schemes (with the exception of Malgovert and Innertkirchen) are directly connected to reservoirs having varying water levels. The water intake has to be designed for these level variations and so has the surge tank, which has to be adapted to all levels in the reservoir. To avoid

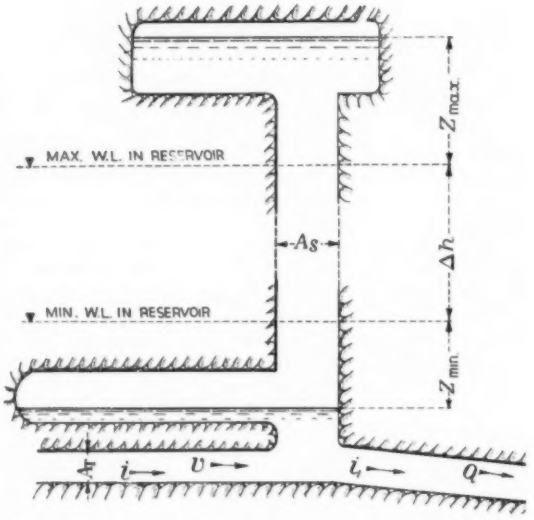


Fig. 3. Surge tank with upper expansion chamber and lower reservoir chamber

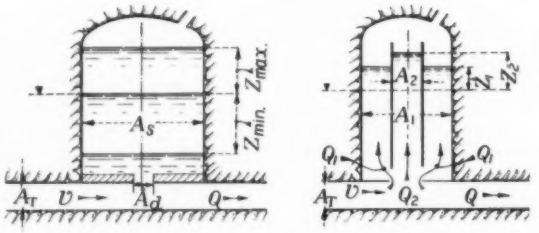


Fig. 4. Restricted-orifice and differential surge tanks

TABLE IV. STATISTICAL DATA ON SURGE TANKS

No.	Surge tanks	Type	Height Y (m)	Diam. main tank (m)	Horizontal area (m^2)	Riser horizontal area (m^2)	Head H_{min} (m)	$\frac{Y}{H_{min}}$
1	Old-Dixence ..	Inclined shaft 2 chambers ..	86·0	2·25	5·9	—	1,561·6	0·055
2	Malgovert ..	Restricted orifice tank ..	43·8	18·30	263	—	750	0·0585
3	Kemano	Inclined shaft (48°) with overflow	63·5	7·63	62	—	730	0·087
4	Innertkirchen ..	Differential with external riser	65	8·50	56·7	11·0	672·30	0·097
5	Verbano-Maggia	Differential with external riser	83	11	95	—	450	0·184
6	Loch Sloy ..	Restricted orifice upper and lower chamber	61	7·92	49·4	—	281 −220	0·277
7	Bersimis Lac Cassé	Restricted orifice tank ..	89	25·7	520	—	253	0·354
8	Chute des Passes	Restricted orifice, overflow ..	59·5	—	1,325	—	156	0·361
9	Isère-Arc.. ..	Restricted orifice, upper chamber	48	16	200	—	150	0·32
10	Lavey	Differential with inner riser and chambers, overflow ..	32·7	20·5	330	86·5	40·6	0·805

too high a shaft the designer will limit the surges by adding reservoir or expansion chambers to the surge shaft, thus causing a slight additional increase in volume. Fig. 4 represents a typical tank designed on those principles. Two surge tanks mentioned in the Tables IV and V require special explanations.

The Kemano tank has been kept exceptionally small in comparison with other tanks of the same series. This tank is provided with an overflow which is very efficient when the full load is suddenly taken off; this decreases the height of the tank above maximum reservoir level (only 50 ft or 15 m above normal full reservoir). In addition, it has been estimated that the worst conditions for taking on load occur when five sets are running and two additional sets are suddenly added to the system. Such a drastic limitation of the "opening conditions" is possible because Kemano is designed to produce industrial power for an aluminium smelting plant, so that the management is in a position to dictate how the smelting plant will be run and how the power station will be loaded. These conditions are exceptionally favourable to a relatively small tank, in spite of the high value of $v_0D=33$ which is its characteristic. The second surge tank which requires some comment is the Innertkirchen surge tank; here the actual

TABLE V. STATISTICAL DATA ON SURGE TANKS

No.	Surge tanks	H Net head (m)	L (m)	Q (m^3/sec)	D (m)	$\frac{L}{H_{min}}$	v_0 (m/sec)	v_0D (m^2/sec)	K	Actual Volume Vol (m^3)	Volume Vol_I formula (3) (m^3)	Volume Vol_{II} formula (7) (m^3)
1	Dixence (Old) ..	1740·10 −1561·60	11,600	10·25	2·25	7·45	2·585	5·8	82	2,843	339	283
2	Malgovert ..	750	14,700	50	4·565	19·60	3·05	13·9	82	12,180	5,100	3,710
3	Kemano 1st stage 2nd stage	730	16,150	198 396	7·63 2×7·63	22·1 22·1	4·32 4·32	33	50* 50*	7,800 15,600	32,000 64,000	21,900 43,800
4	Innertkirchen ..	672·30	10,000	40	3·5	14·88	4·165	14·6	82	4,140	4,250	2,200
5	Verbano-Maggia	450	7,450	44	3·75	16·56	3·98	14·9	82	8,800	4,940	2,650
6	Loch Sloy ..	281–220	2,730	59	4·89	12·4	3·14	15·4	82	8,900	3,930	3,640
7	Bersimis Lac Cassé	253	12,125	416	9·45	48	5·92	56	82	55,700	201,000	77,900
8	Chute des Passes	156	8,700	509	10·45	55·7	5·93	62·0	82	78,000	285,000	110,300
9	Isère—Arc ..	150	16,153	100	6·37	107·7	3·125	19·9	82	17,810	57,000	21,700
10	Lavey	40·6	3,850	200	7·75	95	4·23	32·9	82	34,900	137,000	46,200

* Kemano: two tunnels at second stage, partly unlined. Normal operating with 3,500 cu. secs. per tunnel.

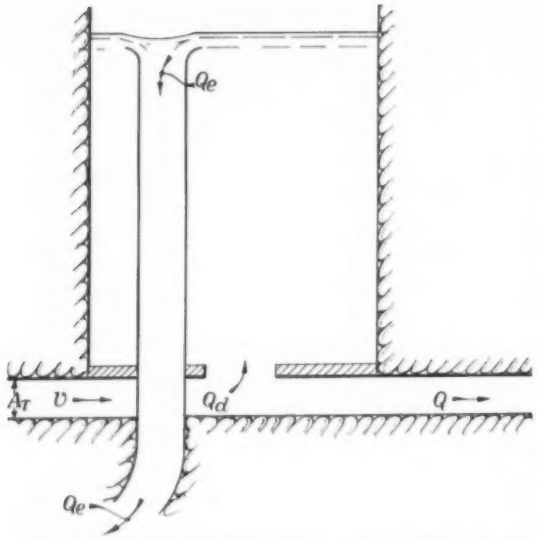


Fig. 5. Surge tank with overflow (Tongland, Scotland)

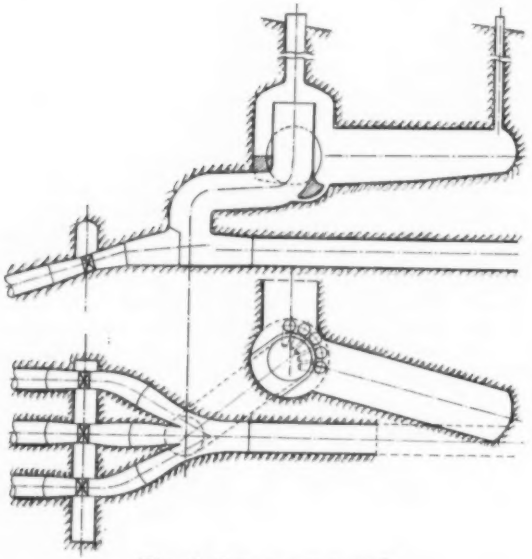


Fig. 6. Lavey surge tank

volume is nearly equal to Vol_I, in spite of the fact that $Y/H_{min}=0{\cdot}097$ only. Innertkirchen is a differential tank with an external riser; the restricted orifice at the bottom of the main tank is a powerful means of reducing the surge in spite of the low value of the ratio Y/H_0.

Tanks No. 7 to No. 10 are all smaller than Vol_I or even Vol_{II}. They are all characterised by relatively large values of the product v_0D ranging from 19·9 to 62, and high ratios Y/H ranging from 0·32 to 0·805. It is apparent that formula (7) giving Vol_{II} was used for dimensioning these tanks and not formula (3) for Vol_I.

Fig. 2 summarises this discussion. It shows clearly the two groups of surge tanks; that is, those characterised by ratios $L/H\leqq 20$, usually connected to high-head stations, with $v_0D=15$ or 17, and the actual tank volume greater than the theoretical values ($Vol>Vol_I>Vol_{II}$). The other group of tanks, usually very large tanks, are connected to low-head, medium-head, or the lower range of high-head power stations; with $L/H\geqq 20$, $v_0D\geqq 20$. These are basically designed so that the actual tank volume is just slightly smaller than Vol_{II}. With Y/H_{min} values larger than $2\lambda=0{\cdot}24$, they are obviously smaller than Vol_I given by formula (3) for $\lambda=0{\cdot}12$.

Some additional comments on how skilled design may result in smaller surge tanks ($Vol<Vol_{II}<Vol_I$) will be given in the next section.

Methods of reducing the volume of large surge tanks. How can it be that some surge tanks have a volume that is well below the values currently assumed to be theoretically correct? It must first be pointed out that for all the tanks to be considered now (Table IV) $Y/H>2\lambda=0{\cdot}24$. The surge is larger than the turbine designer would like it to be and in most cases turbine-gate limiting devices (gate limiters), which suppress to some extent the flexibility of the regulation, have to be used.

But there is more than this in these skilled designs and the surge-tank designer really has further means of reducing the surge-tank volume. These methods have been described and discussed in a recent paper on the "Present trends in surge tank design (1954)," so that the subject can be summarised rapidly here[1, 3]. Thus, the following methods can be used to reduce the

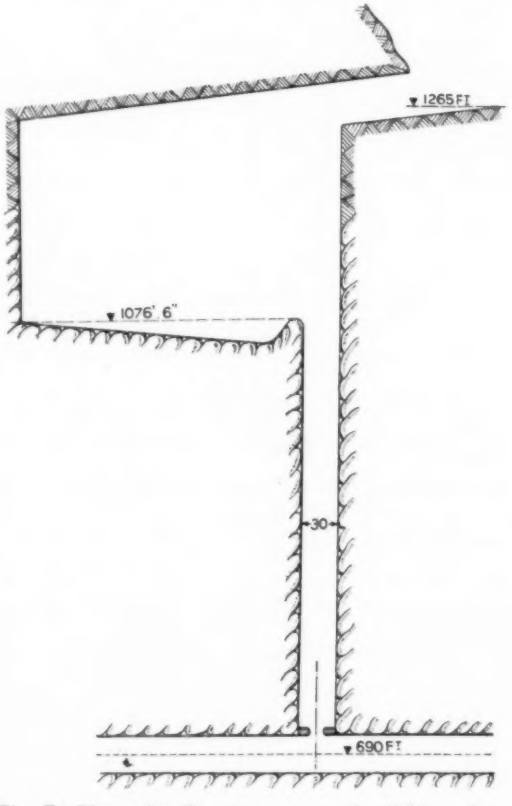


Fig. 7. Chute des Passes surge tank, 1956 project

volume of surge tanks:—

(*a*) Shafts with expansion and reservoir chambers (Fig. 3).

(*b*) Restricted orifice and differential surge tanks (Fig. 4), usually bring about an economy of about 25% to 30% of the volume, compared with single shafts.

(*c*) Surge tank with overflow (Tongland, Scotland) (Fig. 5).

(*d*) A combination of the methods mentioned under (*a*), (*b*) and (*c*). A typical example of this design is the surge tank of Lavey (Fig. 6), while another exists at Chute des Passes, a 1956 project (Fig. 7).

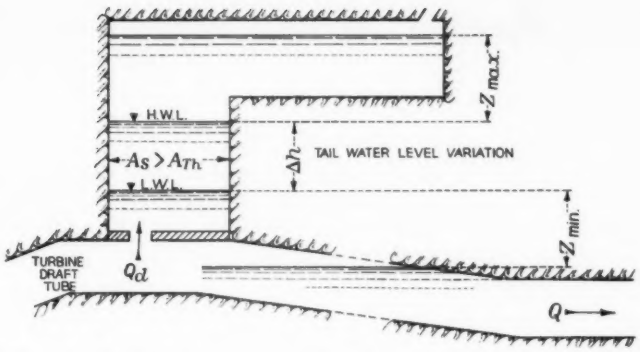


Fig. 8. Typical arrangement for tailrace surge tank for an underground power station

Further economies can be effected on certain tailrace surge tanks build for underground power stations having long tail race tunnels—Swedish type or head-development underground stations, as they are called in the U.S.A. In these the tail race itself, conveniently inclined, can be used as a reservoir chamber for downsurges. Fig. 8 shows a typical tank design suitable for such an underground power station. Basically similar solutions have been adopted for Stornorrfors underground station in Sweden, Glen Moriston (Scotland) and probably others. In such cases the positive up-surge may rise well above the generator floor level, putting additional pressure on the turbine cover. Consequently the power station must be made absolutely waterproof against surges, and the water-hammer effect on the draft tube must be carefully checked and kept low. All designs published at this date show that the tail race tunnel is never unsealed completely, so that the re-entry of air from the downstream end is avoided.

In 1954[1] the writer dealt pretty fully with the cases of possible surge interference, and the addition of surges one on top of the other. In direct opposition to this technique the modern tendency is to limit the downward swing or draw down by limiting the amount of power to be suddenly taken on when the turbines are put on load. It was stated in the 1954 paper that Electricité de France had decided that surge tanks should in future be designed for throwing off full load, the negative surges thus produced being analysed as well as the preceding positive surges. It will be assumed that any negative surge produced by taking on load will have to be limited to an amount reasonably consistent with the negative swing caused by " full load off," thus avoiding any considerable additional expense. The problem is, therefore, reversed, the need for greatest economy being put first and the safety of any new individual station being based on the extensive ramifications of a very large network, which is supposed to damp out all load changes.

This policy has since been adopted by many other large concerns which produce hydro-electric energy. The case of Kemano has already been explained here and the nature of the load there justifies severe economies on the dimensions of the surge tank. A similar policy was adopted at Chute des Passes for the same reason. This policy is now being extended to extremely large surge tanks, Bersimis for example, which are being designed for partial loads only being taken on at any instant and never full load. It is agreed that, if a major trouble occurs on the grid, causing a major short circuit of say of one million hp to occur, the whole grid will be upset and disrupted to such an extent that, when the station comes on the line again, it will be on a relatively slow rate of load increase. The " taking on load " can in such cases, as experts agree, be limited to one-tenth or two-tenths of full load figures.

This trend towards greater design economy is making itself felt to an even greater extent on extensive grids fed by a number of large power stations. It has been agreed that when small stations are being added to such a very large grid, there is no need for them to be provided with an automatic governor with frequency regulation. Regulation can be by hand, just for synchronising the set or for shut down. In such cases can the dimensions of the surge tank be reduced substantially? It was found that suppression of frequency regulation eliminates the so-called " condition of Thoma " but possible interference of oscillation by false manoeuvres may still occur, requiring substantial surge-tank volume. Possibly the best solution may be the suppression of the surge tank altogether, even if more severe water hammer occurs in the pipe line. Such problems are now being investigated, but to our knowledge, no final decision has been taken on these lines. Finally, when dealing with underground power stations of the Swedish type, possible alternative solutions exist with a downstream surge tank, or with partial-acting surge tank (Wettingen, for example, in Switzerland) or solutions with free-flow tunnels. The Krangede station in Sweden and the Hamilton River (alternative project) scheme require no surge tank. There are alternative solutions entirely under pressure. There is no surge tank at all at Picote in Portugal, when a drowned tailrace tunnel discharges under the dam apron. Each case must be examined from the technical, hydrodynamic and economic points of view.

BIBLIOGRAPHY

[1] Ch. Jaeger, Present trends in Surge Tank Design. Proceed. Inst. Mech. Eng., London, Vol. 168, No. 2, 1954.

[2] Ch. Jaeger, Present trends in the Design of Pressure Tunnels and Shafts for Underground Hydro-Electric Power Stations. Proceed Inst. Civil Engineers, Part I, March 1955.

[3] Ch. Jaeger, Engineering Fluid Mechanics, Glasgow, 1956, New York 1957.

[4] Guthrie Brown, Hydro-Electric Engineering Practice, Vol. 1 ch. 18 by O. Elsden, Surge Chambers.

Rotor Handling in Hydro Stations

E. Mean, Ing.A.I.Lg.-A.I.M., J. George, Ing.A.I.Br., and R. Normand, Ing.A.I.Ms.,* suggest a method of handling the rotors of vertical waterwheel generators whereby the height of the machine hall, and therefore, in the case of an underground station, the volume of excavation, can be reduced

IN a hydro-electric station equipped with vertical generating sets the heaviest and bulkiest load to be lifted is the generator rotor, and, indeed, the crane capacity and the height of the machine hall are determined by this requirement. The usual method of handling this load is to employ two travelling cranes brought side by side and with their hooks engaging a lifting beam carrying a central hook from which the rotor is suspended. With such an arrangement, outlined in Fig. 2, the machine hall has to be high enough to accommodate the following: (1) the clearance of the suspended load above the machine-hall floor (or above the top of the stator if above floor level); (2) the rotor itself; (3) the slings between the lifting sleeve on the rotor shaft and the hook of the lifting beam; (4) the lifting beam and its hook; (5) the girders of the travelling cranes; (6) the crane cross carriages with their winches; (7) the clearance above the crane winches. The machine hall must also be wide enough to allow the rotor to avoid other sets when being transported to the service bay.

These requirements tend to the construction of very high machine halls, and in the case of underground stations, to excessive excavation costs, and the authors have developed a method of handling these rotors in such a manner that the height of the machine hall can be drastically reduced.

By way of introduction, however, it may be appropriate to comment briefly on general principles. In handling a heavy load such as an alternator rotor, which needs to be handled only occasionally, speed of lifting is not important, the primary considerations being low cost and safety. With such heavy loads there would appear always to be a certain element of risk in depending on a single hoisting rope—or on two ropes where two cranes are double-banked—and on the brakes of a single winch—or of two winches—and it would seem desirable to increase the number of independent lifting elements so that the failure of any one element would not vitally affect the issue. Unfortunately the use of more than three independent lifting elements introduces the problem of sharing the load evenly without introducing some system of articulation which would reduce the system kinematically to three suspension points or less.

The authors have therefore based their system on the use of a series of oil-operated hydraulic jacks, the number of which can be chosen to suit the particular installation. These jacks are coupled hydraulically so that they share the load evenly, but should any jack become deranged it can be shut off and the load taken by the remaining jacks. They have a comparatively short stroke and operate in conjunction with a ratchet mechanism which holds the load positively while the jack is being returned for the next stroke. Alternative designs have been developed to raise a load from below or to lift it from above. The objection to raising or lowering a waterwheel-generator rotor from below is that it is difficult to guide the rotor to its exact position within the stator, and for this reason the system has been based on the use of jacks disposed on a crane-mounted structure above the rotor and lifting it by means of special chains.

One of these jacks is shown diagrammatically in Fig. 1. The jack *a* engages pins of the double chain *b*, by which it raises the suspended load through a distance of one link. During this movement the spring ratchets *c* are forced back until they finally spring forward under the next pair of pins of the chain, by

* M. Mean is Ingénieur Principal and MM. George and Normand are Chefs de Service of Société Electrorail, Brussels.

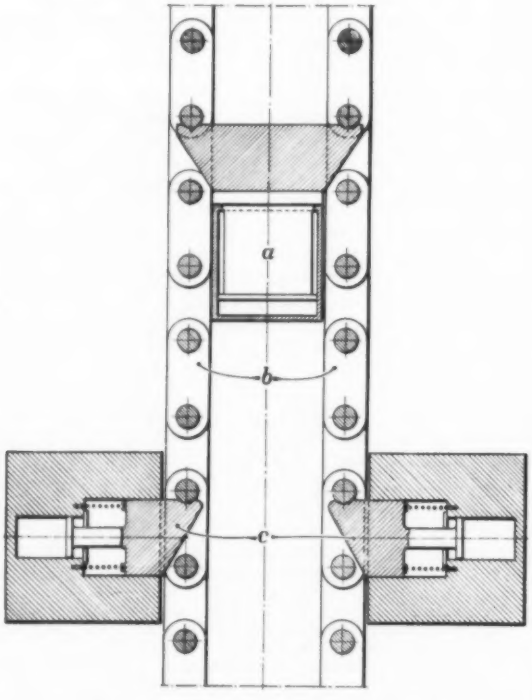


Fig. 1. Arrangement of lifting jack

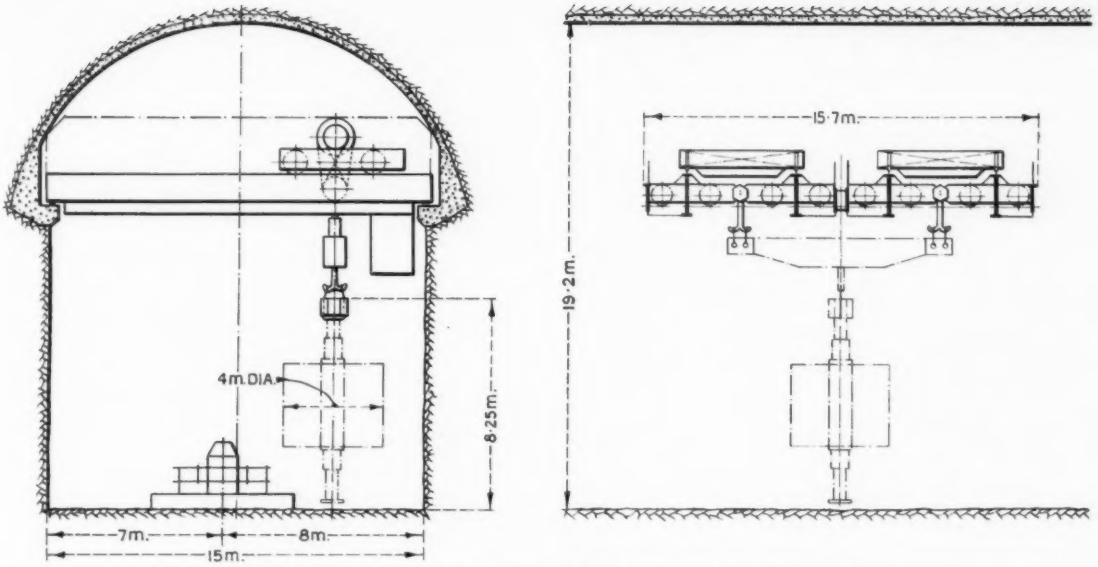


Fig. 2. Underground machine hall required for normal method of lifting rotor

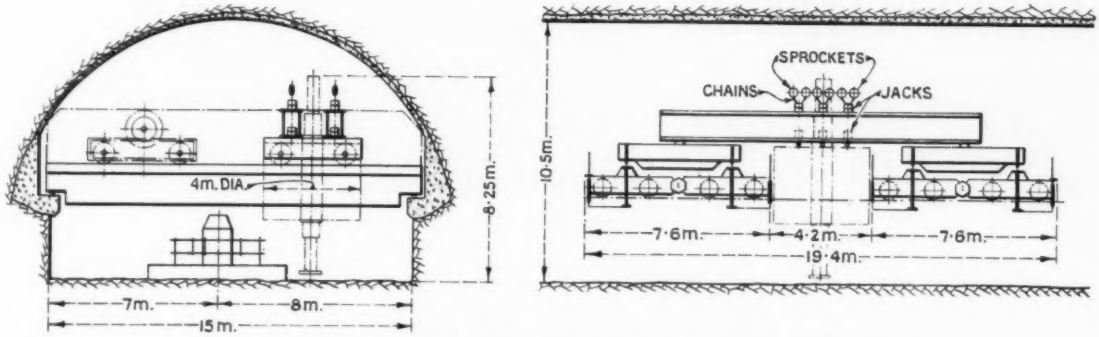


Fig. 3. Underground machine hall for proposed method of lifting rotor

which they hold the load positively while the jack *a* is retreated preparatory to its next stroke.

In conjunction with this jacking system the authors have devised a means of using the power-station cranes in such a manner that the rotor is carried between them instead of being suspended therefrom, with the result that the height of the machine hall can be drastically reduced.

The arrangement is shown in outline in Fig. 3. Two normal overhead cranes are installed, but for rotor lifting they can be mechanically connected at a distance from each other sufficient to accept the rotor between them, and for convenience when so coupled, the two cranes can be controlled simultaneously from one cabin. The normal winch carriages are parked at one end of their travel and disconnected, and, by means of a tackle, a second carriage is placed on the cross runway of each crane. These carriages carry swivel bearings on which is then placed a cross frame consisting of a pair of girders spaced to allow the portion of the rotor shaft above the rotor body to rise between them. These girders carry a suitable number of lifting jacks and chains such as we have described, and when all preparations have been completed the rotor is lifted by the jacks to the position shown in Fig. 3. The load can then be traversed and transported by means of the normal crane controls.

Figs. 2 and 3 show the normal and proposed arrangements for lifting the rotor of an 80 kVA 400 r.p.m. generator, and demonstrate that for a set of this size the height of the machine hall above the generator floor can be reduced from 19·2 to 10·5 m.

NOTE. This account is an extract from an article "La Manutention des Alternateurs dans les Centrales Thermiques et Hydroélectriques" published in *Bulletin Scientifique de l' A.I.M.*, Liége, Belgium, No. 4, April 1957.

Pragnères Penstocks. A handsomely produced brochure received from Établissements Bouchayer & Viallet gives a full account of the two pressure pipelines at Pragnères which operate respectively under static heads of 2,160 m. and 1,830 m. Detailed specifications are given of the lines themselves and other chapters deal with the telpher lines used for their erection, the actual work of erection, their testing and the use of chrome-copper steels in the construction of modern penstocks.

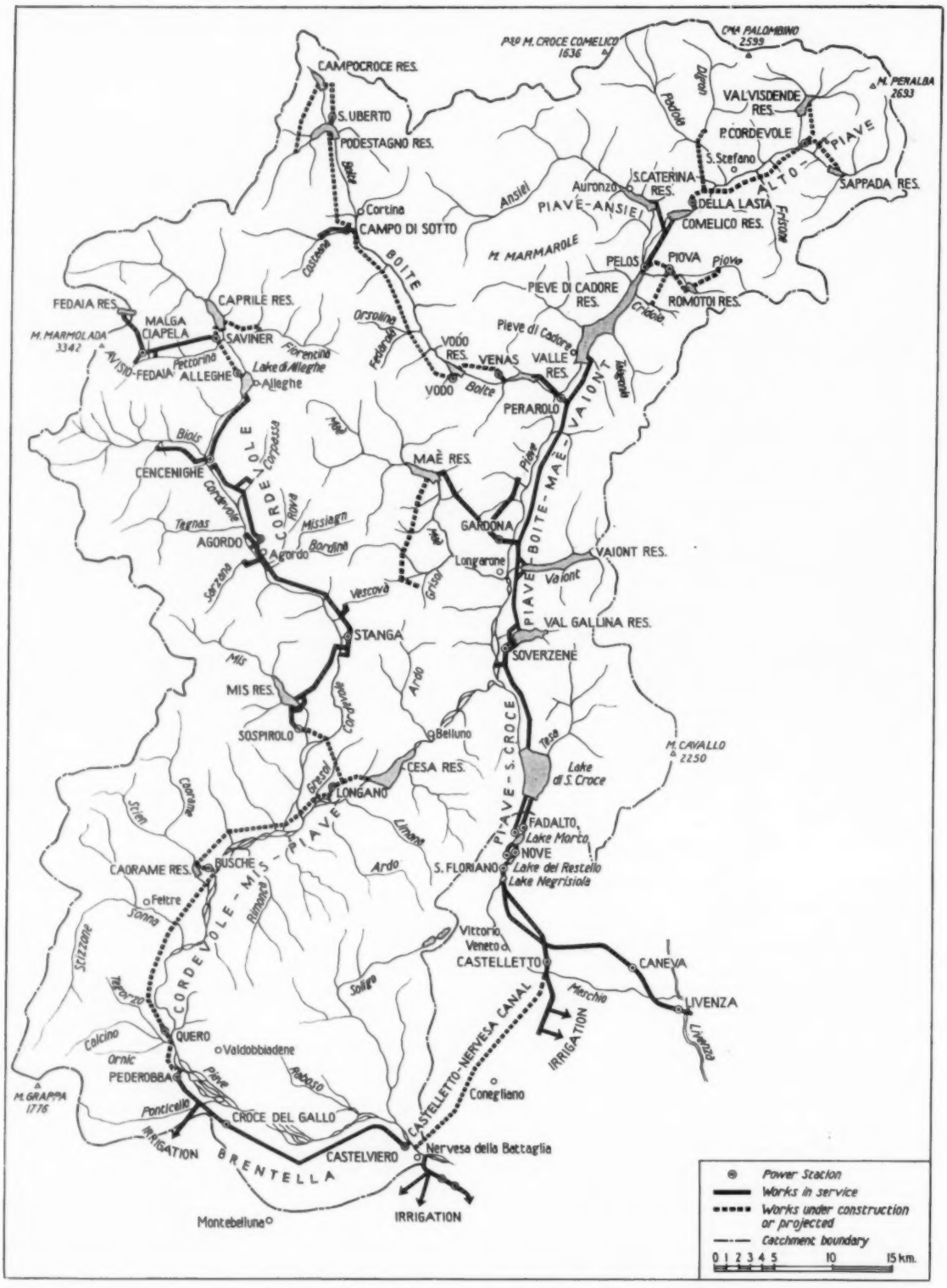


Fig. 12 (Repeated from Part II). Map of Piave basin

Fig. 25. A view of the completed Pieve di Cadore dam

Some SADE Developments

Continuing our study of the Piave catchment, we commence our description of the developments in the north-eastern section, which comprises the main watercourse from its source to Soverzene and thence over the original course of the river through the Lapisini Lakes. This is the most complex of the SADE schemes, and our account of it will be completed next month

PART THREE

IN our previous article we explained how the Piave basin had been divided into two virtually independent catchment areas by diverting the Piave at Soverzene to its original course through the Lapisini Lakes, and we described the developments in the western, or Cordevole, catchment. It is now our purpose to outline the schemes—completed, in course of execution, and projected—for the development of the north-eastern, or Piave catchment. This catchment is planned to furnish ultimately about 1,800 GWh of practically firm power per annum; it is the most productive of the catchments in the Company's territory and contains some of the most interesting engineering.

For convenience of reference we are reproducing on page 180 the map of the Piave basin published as Fig. 12 in our previous article, as it shows the developments that form the subject of this article.

From the development standpoint the basin may be divided into the following sections: (a) the Alto-Piave-Ansiei scheme, covering the headwaters of the

Piave and of its tributary the Ansiei down to Pelos; (b) the Piave-Boite-Maè-Vaiont scheme, covering the stretch from Pelos to Soverzene; and (c) the Piave-S. Croce scheme from Soverzene through the Lapisini Lakes to the Venetian plain along the ancient course of the Piave.

Alto-Piave-Ansiei Scheme

The existing development at the head of the basin was carried out in 1929–32 by Società Forze Idrauliche Alto Cadore—a British-owned mineral company—and was acquired by SADE in 1933. It consists of two reservoirs, one on each river, standing at a common level and supplying a power station at Pelos through a Y connection. Comelico reservoir, on the Piave, is impounded by a double-curvature arch dam 67 m. high and has a live capacity of 1·8 million cu. m. S. Caterina reservoir, on the Ansiei at Auronzo, has a useful storage of 6·7 million cu. m. and has been formed by a gravity dam 59 m. high. Pelos station

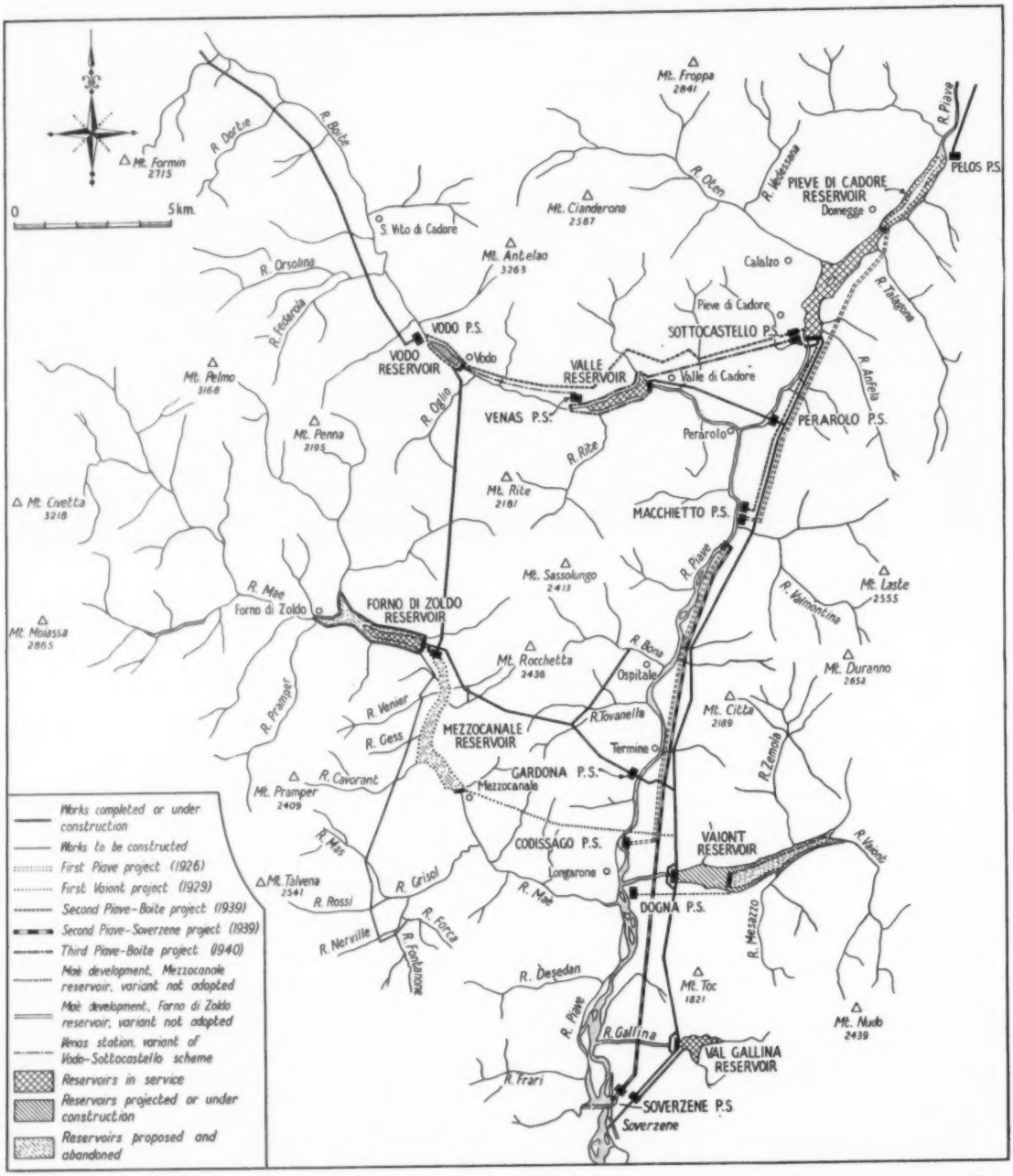


Fig. 26. Map of the Piave-Boite-Maè-Vaiont scheme showing the various alternatives proposed as well as the substantive development

contains three 10 MW horizontal Francis sets. The maximum water level in the two reservoirs stands at an elevation of 830 m., and Pelos tailrace discharges at a level of 683·5 m.

Plans are in existence for the full development of the Piave headwaters down to Comelico reservoir. A reservoir of 11 million cu. m. capacity will be formed on the Piave at Sappada, and the waters of the Cordevole di Visdende will be impounded in a second reservoir of 18 million cu. m. capacity in Valle Visdende. These two reservoirs will supply machines in a station at Ponte Cordevole under independent heads, the capacity of this station aggregating 16 MW. An open channel will convey the tailwaters of Ponte Cordevole station to a 23 MW plant at Lasta, discharging directly into Comelico reservoir, and during its course this channel will pick up the flow from the Frisone on the left, and will be joined on the right by a channel carrying the headwaters of the Padola and the Digon.

It is also proposed to develop the Ansiei from its source in Lake Misurina to S. Caterina reservoir.

On the Piova, which flows into the Piave from the left just below Pelos, a pumped-storage reservoir will be formed in the valley of one of its tributaries, the Romotoi, supplying Piova station, which will also be served by the headwaters of the Cridola, the discharge passing to Pelos station. This development is in the hands of another company.

Piave-S. Croce Development

In terms of plant still in service the Piave-S. Croce section is the first part of the Piave basin to have been used to produce power, and development is now complete. This historical priority is one reason why we propose to describe the S. Croce section at this point in our article instead of following the normal sequence down the river. The other reason is that in planning the Piave-Boite-Maè-Vaiont scheme the effect of such a development on the performance of the Piave-S. Croce section was a vital consideration; thus the significance of the design of the central Piave scheme cannot be fully appreciated without a knowledge of the nature and limitations of the works utilising the water through the Lapisini Lakes. These works are concerned quite as much with irrigation as with power production, and the effect of upstream developments on the fulfilment of the irrigation requirements was an important factor in design.

The original plants in this section were set to work in 1914 and consisted of the old 9,000 kW Fadalto station supplied from Lake S. Croce, and the old 6,000 kW Nove station supplied from Lake Morto. The output from these stations was limited to the water available from these lakes, which were served by a catchment of only 150 sq. km.

The credit for the idea of diverting water from the Piave along its original course through Lake S. Croce belongs to two Italian engineers, A. Pitter and V. Ferniani, who, over the period 1919 to 1929, built up a chain of stations utilising a mean flow of 30 cu. m. per sec. of Piave water withdrawn at a level of 390 m. near Soverzene and discharging at a lowest level of 13·5 m. into the Livenza. Altogether, eight stations are now in service, five of which operate in series. New stations were built at Fadalto and Nove in parallel with the old ones, of 75 MW and 50 MW capacity respectively. A small station, of 4,500 kW capacity,

Fig. 27. Valle di Cadore dam, showing the spillway in action

was built at S. Floriano, between Lake Restello and Lake Negrisiola, and therefrom the development becomes a combined power and irrigation scheme.

The natural outlet of Lake Negrisiola is the River Meschio, a tributary of the Livenza, and a minimum flow is maintained in this river for industrial and agricultural purposes. Below this outlet a double offtake leads, on the one hand, to Castelletto station (5,500 kW), the discharge from which returns to the Meschio at a level of 90 m. for irrigational use, and on the other hand to Caneva station of 36 MW capacity. The tailwaters from this station are partly returned to the Meschio and are partly conveyed to the final plant —the 5,500 kW Livenza station—which discharges to the Livenza at a level of 13·5 m., this water also being used for irrigation.

Piave-Boite-Maè-Vaiont Scheme

The Piave-Boite-Maè-Vaiont scheme is the largest and most important accomplished by the SADE organisation (the Tagliamento scheme, to be described in a later article, will be nearly as large), and is the outcome of prolonged study. Investigational work commenced in 1939, and many alternatives were considered before the final scheme was chosen. Power was first produced in 1951, when Soverzene station was inaugurated, but the Vaiont dam is still in course of construction, and future developments are planned on the upper reaches of the Boite.

In 1939, when studies were undertaken, SADE owned, to the north, the Piave-Ansiei development, comprising Pelos station and its associated reservoirs, and to the south, the Piave-S. Croce development, and the problem was to devise a co-ordinated scheme to develop the section of the river between Pelos and Soverzene.

The scheme adopted is outlined in the general map, Fig. 12, but in Fig. 26, which is confined to the section under discussion, are shown not only the substantive solution but also the various proposals that were considered and rejected.

Under a previous concession granted to Società Idroelettrica Dolomiti (SID), it had been proposed to form a comparatively small reservoir at the Pelos tailrace with a dam near Domegge, and to convey the waters to a station at Macchietto about 3 km. south of Perarolo. This was modified by SADE by increasing the size of the reservoir and using it to receive also the upper waters of the Boite. A dam was to be built near Pieve di Cadore giving a useful storage of 50 million cu. m. at a maximum water level of 677 m. On the Boite a reservoir was to be built at Vodo, whence the waters would be transferred to the Pieve di Cadore reservoir through a station at Sottocastello. A variant of this scheme was to impound a second storage on the Boite at Valle di Cadore, to supply this reservoir from the Vodo reservoir through a station at Venas, and to use the Valle di Cadore storage to supply a lowerhead plant at Sottocastello.

Under any of these variants the discharge from Macchietto station was to be picked up and conveyed either to a station at Codissago or directly to a station at Soverzene.

Fig. 28. The recently completed Maè dam

On the Vaiont a reservoir was proposed having a live storage of 46 million cu. m. at a level of 660 m. and feeding a station at Dogna, just downstream of Longarone, discharging into the Piave.

In the plans finally adopted, these various projects were co-ordinated into a single scheme. The essence of the idea was to connect reservoirs on the Piave, Boite and Vaiont hydraulically by means of a pressure tunnel feeding a single power station at Soverzene. The reservoir on the Piave would constitute the main head reservoir and would be formed by building a dam at Pieve di Cadore. The level of the Vaiont reservoir, which would also provide seasonal storage, would conform to that of the Pieve di Cadore reservoir, allowing for hydraulic losses, and a small compensation reservoir would be constructed near Soverzene station in Val Gallina.

This scheme presented important advantages. In the first place, there were obvious economies in concentrating power production in a single high-capacity station, as opposed to the four or five smaller stations envisaged by the earlier piecemeal proposals. Secondly, by introducing a balancing reservoir at Val Gallina, the pressure tunnel from Pieve di Cadore to Val Gallina—a distance of 24 km.—would only be called on to sustain a flow corresponding to the average load on the station and could therefore be of relatively small diameter, the large tunnels necessary to handle peak-load flow being required only over the 2·5 km. between Val Gallina and Soverzene. Actually the diameter of the main pressure tunnel is 4·5 m. from Pieve di Cadore to Vaiont, 4·7 m. from Vaiont to Val Gallina, and between Val Gallina and Soverzene there are two 5 m. diameter tunnels in parallel. This layout also secures an important saving in the cost of the surge tank, as it is called upon to accept the fluctuation in a tunnel only 2·5 km. long as against one of 27 km.

A further major consideration was the improvement this scheme would effect on the operation of the S. Croce development. The power plants on this section were capable of a considerably increased output, but the local storage could not readily be increased, as it was impracticable to raise the level of S. Croce reservoir any further owing to the nature of the embankments and the proximity of a railway and national roadway. It was reckoned, however, that the upstream seasonal regulation afforded by the new scheme would raise the output of the Piave-S. Croce section from 650 to 800 million kWh per annum. The effect on irrigation would be equally beneficial, for

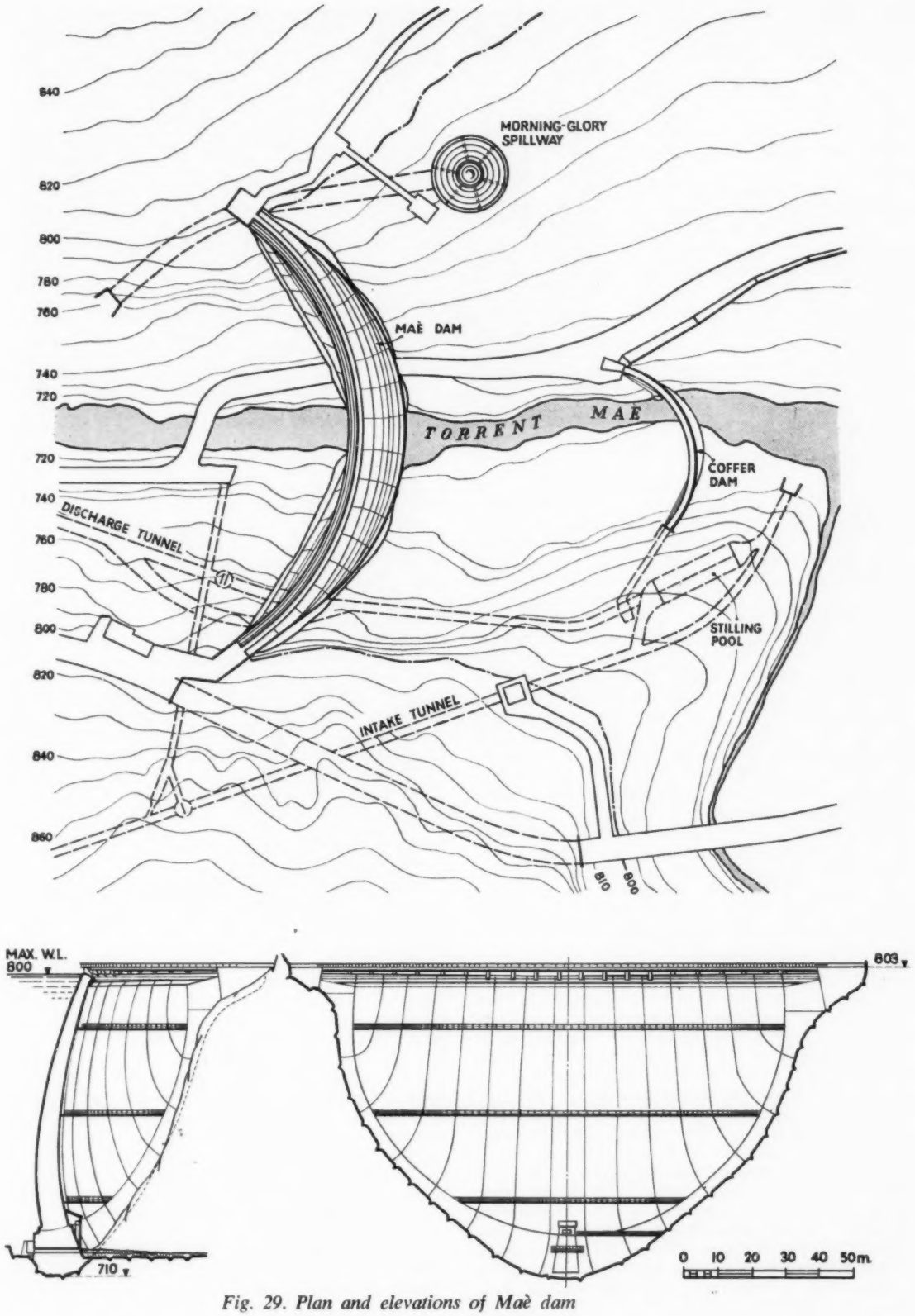


Fig. 29. Plan and elevations of Maè dam

the amount of water passed through to the left-Piave irrigation system would be increased by 25%, even taking into account the statutory responsibility to maintain a minimum compensation flow of 5 cu. m. per sec. in the Piave bed through the Belluna valley.

It was possible, too, to plan the construction of the scheme in stages, to obvious financial and practical convenience, and the development has actually been carried out on this basis. The first stage, completed in 1950, included the Pieve di Cadore dam, the tunnel from Pieve di Cadore to the site of Val Gallina dam, where a bypass was constructed, one of the tunnels from Val Gallina to Soverzene, and Soverzene station with two 55 MW generating sets. The second stage, completed in 1951, included Valle di Cadore dam on the Boite and the tunnel connecting this reservoir to the main tunnel, the second tunnel from Val Gallina to Soverzene station, and the third 55 MW set. The fourth and last 55 MW set was commissioned in 1956, and the final stage, now in progress, is the construction of the Vaiont dam, which it is hoped to complete in 1960.

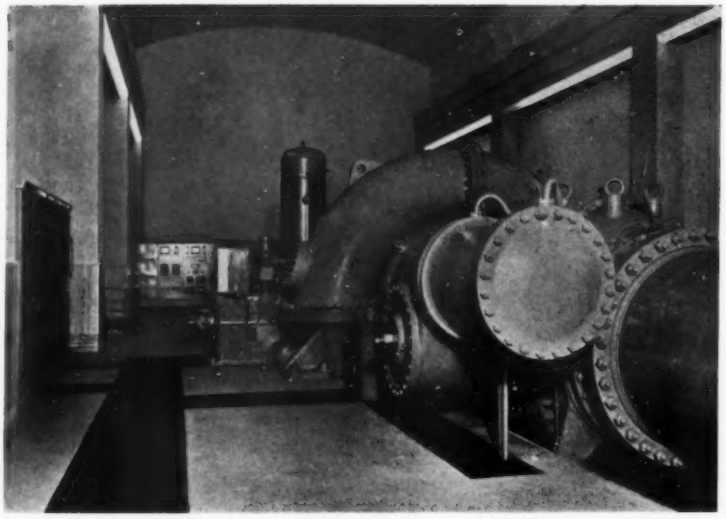


Fig. 30. Interior of Gardona power station

At the time these proposals were drawn up, the Maè was under the control of a separate organisation, Compagnia Industrie Montanistiche, who had planned the independent development of this river down to its confluence with the Piave. The incorporation of the Maè into the final scheme, therefore, took place later on. It was then decided to construct a reservoir on the Maè backing up to Forno di Zoldo, and to connect it hydraulically to the main pressure tunnel by an inverted syphon crossing the Piave watercourse. To take advantage of the head available from Forno di Zoldo reservoir, a station was to be built at Gardona. This station was placed in service in 1955, using water impounded by a temporary dam across the Maè upstream of the main dam site. The main dam was completed at the beginning of 1957.

Pieve di Cadore Reservoir

The maximum water level of Pieve di Cadore reservoir was automatically fixed by the level of the Pelos tailrace at 683·5 m., but the selection of the most suitable dam site presented a great deal of difficulty. The site at Domegge, proposed under the earlier scheme, lent itself to the erection of an economical structure, but the live storage procured would have been only 3 million cu. m., and the main pressure tunnel would have been 8 km. longer than the one actually driven.

From the standpoint of storage capacity and of length and diameter of tunnel the best solution would have been a dam as near as possible to the confluence with the Boite, but no practicable site was available. The least unfavourable site was at Pian delle Ere near Pieve di Cadore, but even this was far from ideal. This site is in the form of a large trapezium, about 300 m. wide and 55 m. high, cut in the Dolomitic limestone, but to the right of the section the river has cut out a deep gorge, 55 m. deep below the valley floor.

The filling of this gorge in a manner harmonising functionally with the construction adopted for the dam itself posed a difficult design problem, and many alternatives were considered, and calculations and model tests carried out, before the final solution was reached.* This took the form of a concrete plug filling the gorge and surmounted by a plain gravity dam arched in plan (Fig. 25). The dam has a mean height of 55 m. and a maximum height from the bottom of the plug of 112 m. Its crest length is 410 m. on a chord of 308 m., and it contains 377,000 cu. m. of concrete. The contractors for the dam were Impresa Filli Monti, Auronzo.

Pieve di Cadore reservoir has a total storage of 68·5 million cu. m., and a useful capacity of 64·3 million cu. m.

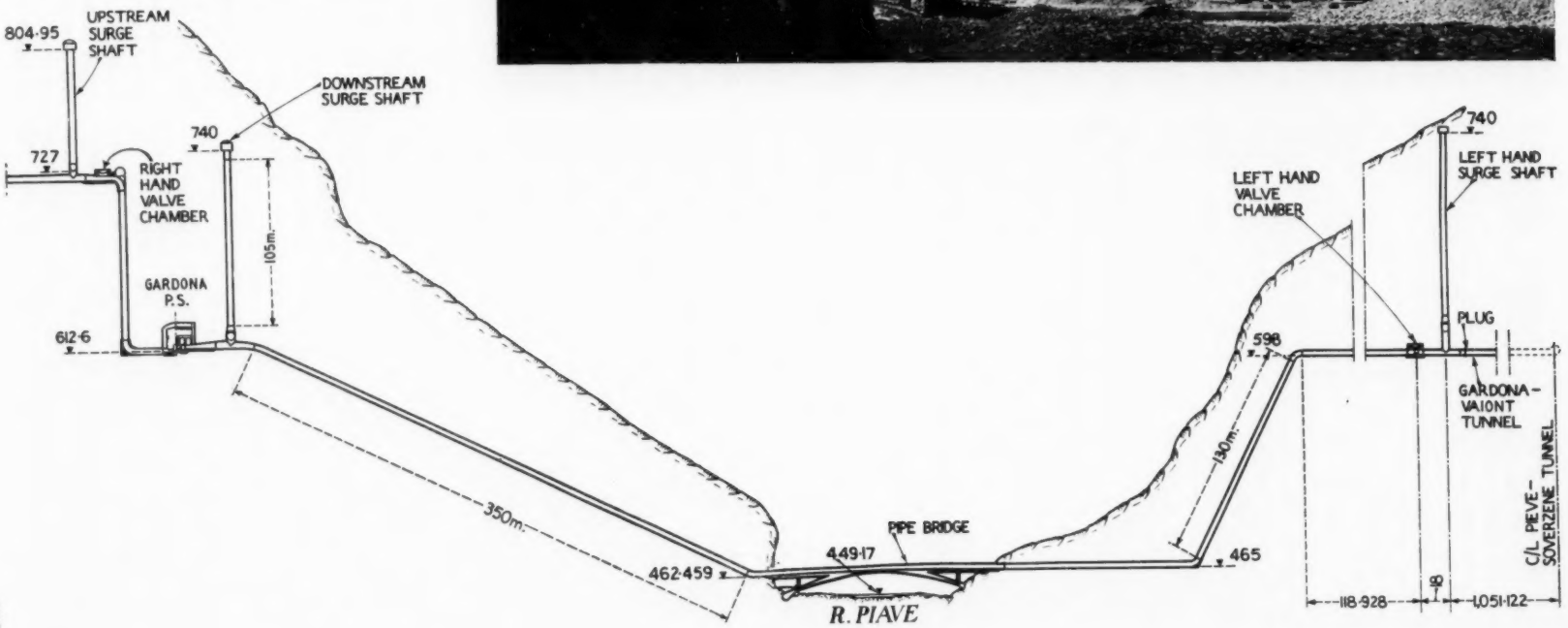
Perarolo Station

When the scheme was being planned it was suggested that during its construction it might be possible, at moderate expense, to derive some power from the partial storage in Pieve di Cadore reservoir before Soverzene station was brought into service. A suitable location for a temporary power station was found near Perarolo, where a penstock tunnel was carried down to a station at river level from the main pressure tunnel at a point 3,370 m. from the Pieve di Cadore intake, and a 21 MVA reserve generating set from Pelos station was transferred thereto. The head of 130 m. was similar to that obtaining at Pelos. Perarolo station commenced to generate at the beginning of 1949—as soon as the plug of Pieve di Cadore dam had been sealed after only one year's concreting, and the first 3½ km. of main tunnel had been driven. It ran for upwards of two years before Soverzene station was commissioned and thereafter supplemented Soverzene as required pending its completion.

* It is much to be regretted that considerations of space preclude a detailed discussion of the design and construction of this and other interesting dams of the SADE developments, but a full account is given in Dr. Semenza's paper "The Most Recent Dams by the Società Adriatica di Elettricità in the Eastern Alps," *Proc. I.C.E.*, Vol. I, No. 5, September 1952. An illustrated summary of this paper was published in WATER POWER, May 1952, p. 164.

Fig. 31. The reinforced-concrete pipe bridge across the Piave at Gardona

Fig. 32. Arrangement of the inverted syphon connecting the Maè development with the Piave-Boite-Vaiont system



Developments on the Boite

It will be remembered that according to the original proposals it was planned to form a reservoir on the Boite at Vodo and to convey the waters either directly to the station on the bank of Pieve di Cadore reservoir at Sottocastello or to a station at Venas discharging to a lower reservoir on the Boite at Valle di Cadore, whence a tunnel would connect to a lower-head station at Castello.

Either of these alternatives involved a large tunnel 4,800 m. long between Valle di Cadore and Sottocastello, and when the question of the route for this tunnel came to be examined it was seen that, owing to the mountainous nature of the terrain, no less than 4 km. of this tunnel would have to be driven without adits, the only method of intermediate entry being by means of very deep construction shafts.

A means of avoiding this difficulty was available by following a route alongside the Boite, but at first this was rejected on the score of geological uncertainties. A reappraisal of the situation, however, led to renewed and detailed studies of a route following the direction of the Boite, on the basis of a tunnel connected through an inverted syphon crossing the Piave valley to the main pressure tunnel instead of discharging into Pieve di Cadore reservoir. This route was not only somewhat shorter than that to Sottocastello (4,420 m. as against 4,800 m.), but the maximum distance between adits was reduced to 2,512 m.

A factor that helped to clinch the decision in favour of this revised scheme was that the Perarolo penstock tunnel, which was already in existence, was ideally suited to form one leg of the proposed syphon, and the obvious course was to make use of it.

Natural conditions virtually forced the choice of Valle di Cadore as a dam site for impounding the Boite, but even here there were difficulties to surmount. The site consists of a narrow gorge cut in the dolomitic limestone, but in its upper part the gorge widens out sharply over a shoulder of dolomite. The strata dip deeply from the right to the left flank and towards the top of the shoulder the dolomite is interlaid with calcareous shale. The narrow part of the gorge lent itself admirably to the construction of a cylindrical arch dam, but to have raised the dam to a height of optimum storage would have necessitated a structure standing on the shoulder that would have imposed undesirable stresses on this somewhat uncertain ground. On the other hand, to reduce the storage level to that corresponding to the head in the pressure shaft at the junction point (allowing, of course, for tunnel head losses) would have rendered the reservoir virtually useless for storage. Nevertheless, comparatively little additional cost would be incurred by raising the storage level to 705 m., corresponding to the highest stratum of sound dolomite in the shoulder, and eventually a level of 706·5 m. was chosen, 23 m. above that of the Pieve di Cadore reservoir.

Valle di Cadore reservoir thus functions as a short-period regulator of the flow in the Boite, seasonal regulation being left to the main reservoirs, and its level fluctuates by some 20 m. The gross storage capacity is 4·9 million cu. m.

The dam (Fig. 27) is a dome-type structure 61·25 m. high and containing 4,770 cu. m. of concrete. To protect it from frost and thaw stresses it is faced on both sides with prefabricated concrete blocks, which were not taken into account in the strength calculations. Use has been made of the rock shoulder to construct a large controlled spillway (Fig. 27) to the left of the dam. This is supplemented by a ground sluice and by a free spillway in the centre of the dam parapet. The joint contractors for the dam were Impreza Ing. De Conz, Pedrelli & C., Bellano, and Imprezo Ing. Zadra, Bellano, injections being carried out by Soc. Gonsonda, Milano.

Projected developments in the upper reaches of the Boite (see Fig. 12) comprise a reservoir at Campo Croce supplying an 8,600 kW station at S. Uberto, a 39 million cu. m. reservoir at Podestagno feeding a 15 MW station at Campo di Sotto, a 21 MW station at Vodo discharging into a reservoir, and finally a 19 MW station at Venas discharging into Valle di Cadore reservoir. A 2,100 kW plant at Campo di Sotto has been in operation since 1948 using the waters of a mountain stream, the Costeana.

Exploiting the Maè

When the water rights of the Maè were acquired from CIM the initial investigations were naturally directed towards the establishment of a reservoir in hydraulic balance with the Piave-Boite-Vaiont system. To meet this condition it would have been necessary to construct a reservoir at Mezzocanale (see Fig. 26), which would have provided a storage of 35 million cu. m. at the level required, but the dam would have been so large that its cost would have been prohibitive.

An excellent dam site, however, was available higher up the river at Pontesei, where the nature of the terrain would have permitted the construction of a dam 120 m. high, giving a maximum storage level of 830 m. The resulting reservoir would have had a capacity of 32 million cu. m. and would have afforded seasonal regulation of the river.

Unfortunately, such a reservoir would have submerged part of the village of Forno di Zoldo and a great deal of cultivated land, and would have interfered with the operation of certain small upstream plants. Furthermore, it was actually unnecessary for this reservoir to provide seasonal regulation of the Maè, as this function could be taken care of by the main reservoirs in the Piave-Boite-Vaiont system, and it was sufficient for the Maè reservoir to compensate for periods of low flow. In fact, having regard to the seasonal regulation afforded by the system, the main value of any reservoir on the Maè lay in its ability to divert the waters of the Maè for use in Soverzene power station.. There was also the advantage of a usable head above the hydraulic gradient of the main system, but this was of secondary importance.

After weighing up these considerations it was decided to build a dam at Pontesei 93 m. high, giving a storage of 9 million cu. m. at a level of 800 m., which was sufficient to firm up the average flow. This reservoir was to be connected with the Piave-Soverzene pressure tunnel by means of a pressure tunnel about 8 km. long, followed by an inverted syphon crossing the valley of the Piave.

With this reservoir a net head ranging from 62·5 to 150 m. over the piezometric level in the main system became available, and it was decided to introduce a small underground power station, at Gardona, into the upstream leg of the syphon. As the system was to be closed, this station would operate under counter-pressure, and, as just stated, would be subjected to a

wide range of head. This posed difficult questions of stability, and it was decided to simplify the problem by operating the station at a predetermined constant load. Surge chambers were necessary both upstream and downstream of the station, but by adopting the foregoing procedure it was possible to design these chambers merely for a sudden rejection of load, as the load would always be applied under control. A third surge chamber was necessary at the end of the downstream leg of the syphon to guard against the results of an emergency closure of the valve communicating with the main pressure tunnel. The hydraulic system, showing the surge chambers, power station, and syphon, is outlined in Fig. 32. It was the subject of detailed calculations which were checked by tests on a model.

Maè dam, completed at the beginning of 1957, was built by Lodigiani, Milan, grouting being performed by Soc. Gonsonda, Milan. It is seen in Fig. 28, and drawings are given in Fig. 29. It is a dome-shaped structure with the peripheral joint favoured in SADE designs for this type of dam, and has a central free spillway.

The pressure tunnel between the reservoir and Gardona station is 8,093 m. long and 2·75 m. in diameter, and involved driving a distance between openings of 6,450 m. (including the adits). Seeing that the tunnel was expected to be a wet one to drive, it was thought that to attempt to cut such a length at a constant downward gradient would create difficulties in keeping the workings clear of water. It was therefore decided to drive from each end at a slight upward gradient, and to cut a suitably vented air chamber at the apex formed by the junction, to withdraw any air bubbles entrained when the tunnel was in service.

Gardona power station (Fig. 30) contains a single Franco Tosi horizontal Francis turbine, the draft tube of which forms the continuation of the downward leg of the syphon. It drives a TIBB alternator at 500 r.p.m., and at the maximum head of 150 m. the set develops 20 MW. As already mentioned, the turbine has to run on heads ranging down to 62·5 m. To enable Maè water to pass to the Piave-Soverzene tunnel independently of this set, a Franco Tosi pressure-reducing bypass valve is installed.

The legs of the syphon are made of 2 m. diameter prestressed concrete pipes which are packed solid into the tunnel, and the syphon crosses the Piave by means of an unusually elegant ferro-concrete pipe bridge (Fig. 31) having a span of 104 m.

(To be continued)

Scorzé and Colunga Substations. We understand that there was a slight mis-statement in the list of contractors in Part I of this series of articles, and that the circuit breakers and instrument transformers at Scorzé and Colunga were supplied by Officine Elettromeccaniche Galileo di Battaglia Terme S.p.A.

New Arch Dams in Italy

Arch dams, and particularly dome dams, are becoming one of the most characteristic structures in Italian civil engineering. Seventy single-arch structures (arch, dome and arch-gravity) are in service, about 40 of them having been built since the second world war. This large development is due to the characteristics of Alpine and Apennines valleys, many of which are narrow and deep and are therefore suitable for structures of this type. Moreover, arch dams permit a substantial reduction in the concrete volume —a factor largely in their favour as concrete is the chief cost item in Italy, the labour cost generally being lower than in other countries. Further, the exceptional resistance of arch structures is widely recognised in Italy, and is confirmed by the latest constructions and by extensive laboratory investigations.

One of the most recent dome structures is the Forra dei Camini dam on the river Avisio (Trento), which was completed in the last months of 1957. Its maximum height is 63·50 m., the crown length 93·50 m., and the chord length 81 m. The volume is approximately 25,000 cu. m., the thicknesses ranging from 9 m. at the base to 3 m. at the crown. The central part of the crown forms a spillway 36 m. wide. Extensive grouting was required in a moraine deposit which covers an old river bed on one side of the dam. Another outstanding structure is the new Specchieri dam in the Leno Valley, completed by the Verona Municipality at the end of 1957. This elegant dome structure—markedly curved in the horizontal plane—is over 250 m. high and rests on a series of concrete arches poured under the general foundation plane. Its chord is approximately 100 m. The thickness is about 16 m. at the base and 2·85 m. at the top.

The recent Beauregard dam in Valgrisanche is of the arch-gravity type. It is 132 m. high, has a crest length of 408 m., and contains 450,000 cu. m. of concrete. The capacity of the reservoir is 70 million cu. m. Two important arch-gravity dams have also been completed in Sardinia in December, 1957, which are regarded as basic factors in the agricultural amelioration scheme of the island. Stored waters are chiefly used for the irrigation of the Campidano plain in the central part of the island. The Flumendosa dam is the larger one. Its height is 119 m., crest length 292 m., concrete volume 315,000 cu. m. The other structure, the Monte su Rei dam on the Rio Mulargia, is 100 m. high, with a volume of more than 200,000 cu. m.

Among the structures still under construction is the Frera arch-gravity dam in Val Belviso (Lombardy), 138 m. high, with a crest length of 315 m. and estimated to contain 430,000 cu. m. of concrete. The thickness will be 33·70 m. at the base and 5 m. at the top. It will be built in successive stages, the lower half having a reduced thickness, which will be increased before the upper half is constructed.

The Vaiont dome dam, the excavation work of which is almost completed, will be the highest dome structure in the world (265 m.). It will be described in our SADE article next month.

Porcelain Insulators. A new film, "Porcelain Insulators In The Making," which has been produced for Doulton Industrial Porcelains Ltd., tells the story of manufacture and shows graphically how important it is that every stage in the production should be observed and checked by men with a keen appreciation of the qualities of clay, backed by modern manufacturing and research techniques.

Vibration Tests on Weirs and Bottom Gates

By DR. ING. K. PETRIKAT, Chief Engineer and Head of the Hydraulic Laboratory, Maschinenfabrik, Augsburg-Nürnberg A.G. Gustavsburg Works

PART FOUR

GENERALLY speaking, any type of rubber seal employed on sluice gates, lock gates and bottom-outlet gates is subject to vibration, in the same manner as in the pressure-chamber seal, if water rushes through a narrow gap produced for some reason or other. Fig. 30 shows a deep gate which, in the closed position, is sealed by a rubber section in the upper horizontal part. The rubber seal is fastened to the armature and its high elasticity ensures efficient tightness in the closed position. With the gate slightly raised (Fig. 31a) water quickly flows through the gap between skinplate and rubber section, and the upward pressure resulting from the high velocity pushes the rubber seal against the unmachined gate (Fig. 31b). At that moment the flow and thus the upward pressure cease; the rubber seal then springs back into the old position (Fig. 31a), frees the gap and once more allows the water to flow and the upward pressure to form. This oscillatory motion chatters the gate and hoist and destroys the seal. This can be remedied either by shaping the sealing rubber in such a way that it will not extend as far as the skinplate, and consequently always leave a gap free (Fig. 31c), or by providing a steel lining which will diminish the elasticity of the rubber seal. With the seal fitted to the gate and not to the armature, these difficulties do not arise.

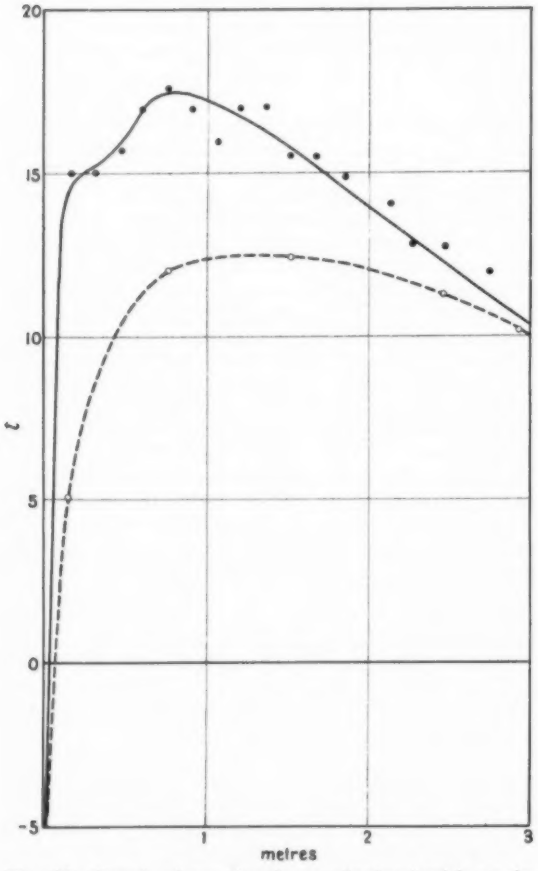


Fig. 28. Graph of tractive force obtained with strain gauges. Full line, raising of gate, and broken line, lowering of gate. Weight of gate, 7 tons; maximum of non-stationary forces $C_{AR}=0{\cdot}015$

Elastic members in contact with rapidly flowing water are potential sources of vibration and should be avoided in the design of gates, especially if the motion of such members results in a change in the cross-sectional area of the gap.

Bottom Outlet Gates

Bottom outlet gates deserve particular attention because of magnitude of the energy stored and the disastrous consequences that vibration may have. As the height of dams increased to 100 m. and over, it became necessary to make a close study of the flow conditions in these gates. When the gates are partly open, the mixing of water and air is liable to occur, and when the speed of flow exceeds 25 m. per sec., a very violent interaction of the water undershooting the gate and the air in the upper part of the gallery, begins to take place. Certain positions of the gate favour the formation of air bubbles which expand very noisily as they emerge from the gallery, causing a pulsating force to act upon the gate, hoisting gear and dam.

The design and arrangement of the gates in the dam, therefore, are determined by:

(1) Magnitude of the vibration inducing forces.
(2) Vibration frequency; this is important in order that resonant vibration at the gate and the dam may be avoided.
(3) Causes of pulsating forces.
(4) Applying the most important laws relating to model tests to full-scale results.

The conditions under which air and water mix with partly-opened bottom gates formed the subject of a paper presented at the Minnesota (U.S.A.) Interna-

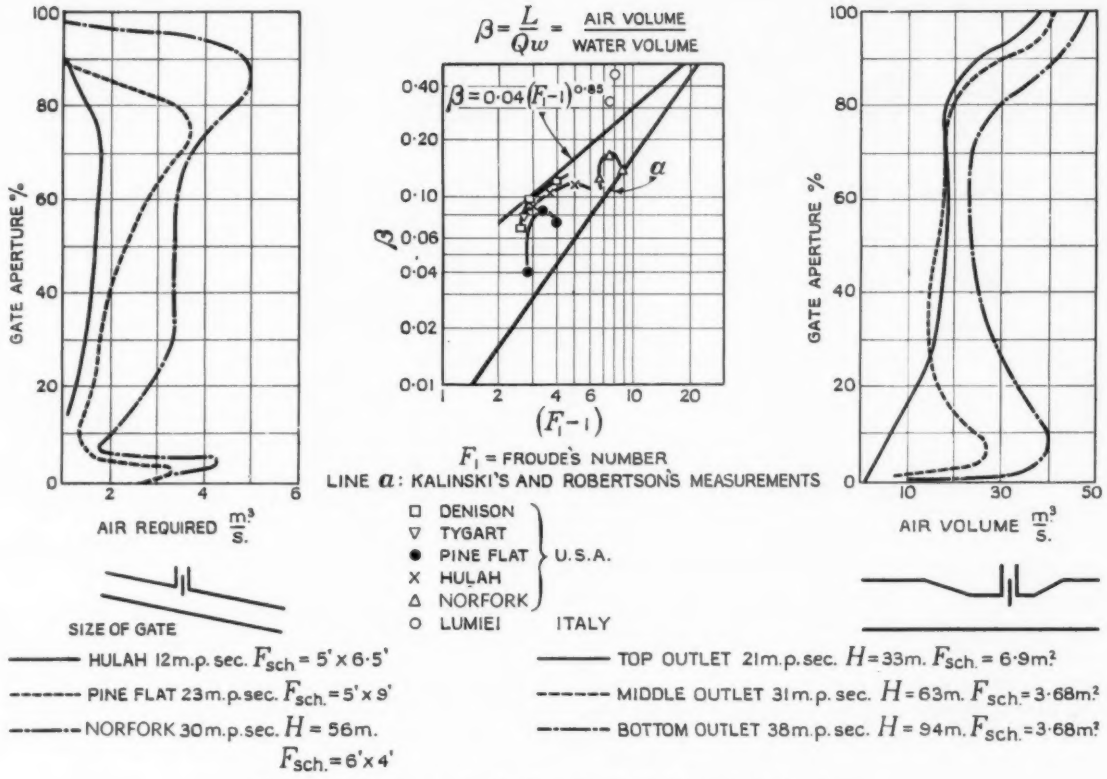

GATE APERTURE %
AIR REQUIRED m³/s.
β = L/Qw = AIR VOLUME / WATER VOLUME
β = 0·04 (F₁−1)^0·85
α
F₁ = FROUDE'S NUMBER
LINE α: KALINSKI'S AND ROBERTSON'S MEASUREMENTS
DENISON
TYGART
PINE FLAT
HULAH
NORFORK
LUMIEI
U.S.A.
ITALY
AIR VOLUME m³/s.
SIZE OF GATE
HULAH 12m.p.sec. F_sch = 5' x 6·5'
PINE FLAT 23m.p.sec. F_sch = 5' x 9'
NORFORK 30m.p.sec. H = 56m. F_sch = 6' x 4'
TOP OUTLET 21m.p.sec. H = 33m. F_sch = 6·9m²
MIDDLE OUTLET 31m.p.sec. H = 63m. F_sch = 3·68m²
BOTTOM OUTLET 38m.p.sec. H = 94m. F_sch = 3·68m²

Fig. 29. Measurement of air volume on bottom-outlet gates

tional Hydraulics Convention[4]. The values calculated on the basis of plausible assumptions concerning the roughness of the water surface are so far out of agreement with the volumes of air measured in existing dams that the idea of thoretical predetermination of air requirements was abandoned. The same paper contained information on Kalinski's and Robertson's model tests covering the carryover of air. These tests, which were made in a flume 150 mm. wide, established the dependence of the factor β on Froude's number (Fig. 29) where β is the ratio of the air quantity to the quantity of water discharged and Froude's number is related to the height of the gate aperture:

$F_1 = V_1/\sqrt{g\ y_e'}$ (y_e = flow restriction at the gate).

However, the β-values calculated from measurements made on existing dams are normally much higher than those obtained from model tests. Campbell and Guyton, therefore, came to the conclusion that neither model tests nor theory are satisfactory and that it is better practice to enclose all measured β-values in an enveloping line $\beta = 0{\cdot}04\ (F_1 - 1)^{0{\cdot}85}$ and to use this empirical function for determining the air requirements of bottom gates.

Measurements taken on the Lumiei dam[5] gave a value of the order of 0·3 to 0·4, that is, twice the highest β-value measured in the U.S.A. and nearly three times that obtained from the model tests.

As a result of this poor agreement between model test results and the empirical American curve with the β-values measured by ourselves, it became necessary to clarify the essential conditions that determine the formation of water and air mixing.

Such information was particularly necessary in view of the necessity to dimension the venting pipes correctly, as any inadequacy here entails excessive air speed, and the vacuum at the gate so caused will result in cavitation, violent back-flow, turbulence and vibration. Figs. 29 and 32 show the aspirated quantities of air plotted against the gate lift. The air requirements in three U.S.A. dams with different water levels and different water velocities are given as a function of gate aperture and the values obtained on the Lumiei Dam are also included. The configuration of American bottom-outlet galleries differs from their Italian counterparts inasmuch as in America the cross-sectional area upstream and downstream of the gate is the same, whereas the Italian galleries are restricted upstream and flared downstream.

In spite of the marked difference in gallery shape, it has been established by measurement that air requirements in either case drop to zero with low water velocities and gate lifts. Under conditions of higher velocities—23 m. per sec. and over—air requirements in both cases reach a peak amounting to about 80% of the maximum air volume.

If the β-value is determined for the amount of water discharge in this zone, the figures obtained are far in excess of the maximum values indicated in the centre graph.

These high air requirements are attributable to the fact that the water is completed turned into spray under conditions of limited gate lift and high flow velocity. The water droplets carry proportional amounts of air with them and it is this which accounts

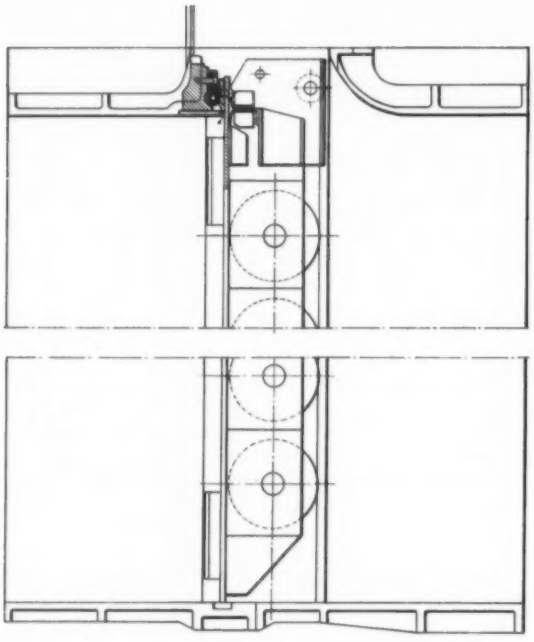


FIG. 30

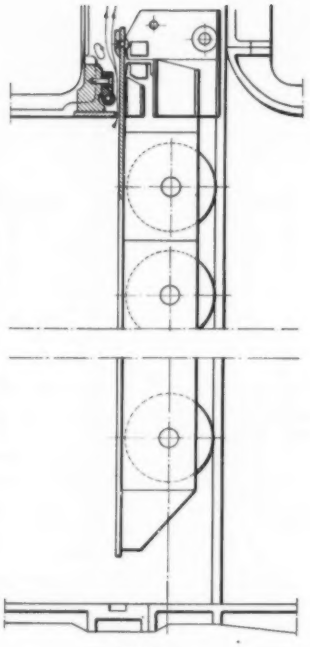


FIG. 31a

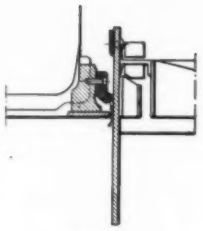


FIG. 31b

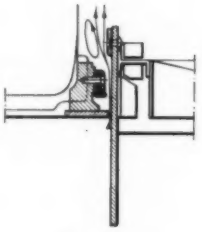


FIG. 31c

Fig. 30. Deep gate with head and side seals of the musical-note type, in closed position. In Fig. 31a water is shown rushing through the gap as the gate is lifted, while in 31b the rubber section is shown deformed by the sub-pressure and bearing against the non-machined, slightly receding skin plate. Fig. 31c shows an improved shape of rubber seal with which no vibration occurs

for the high air demand. If the gate lift is slightly increased, only a small part of the water is turned into spray and much less air is required, despite the greater water discharge. If the gate lift is still further increased, the air demand in both the American and Italian cases goes up again. In America it reaches a maximum with 75% to 85% aperture, while the maximum for the Italian dam occurs when the gate is completed raised and amounts to about twice the American measurements.

This difference is caused by the difference in the gallery shapes. In America, the air mixing with the water enters from the top only, but in the Italian dam it is admitted from three sides. The gallery behind the gate is only 38 to 54 m. long and the back pressure caused by friction is not enough to make discharge possible without inflow of air. Thus, the air demand at Lumiei is the greatest when the gate is completely raised. Conditions are similar to those of the jet-flow gate shown in Fig. 32.

The geometrical dimensions of the galleries and their location with respect to the Lumiei Dam are illustrated in Fig. 33. The three bottom outlets are arranged in the rock of the left abutment at a depth of 33 m., 63 m. and 94 m. They are hydraulically controlled and each is composed of a regulating gate and emergency gate. The cross-sectional areas are given in Fig. 33. They are 6·9 sq. m. at the top outlet and 3·68 sq. m. at the middle and lower outlets.

Vibration measurements showed that operation of the bottom outlets induces vibration in the dam of the order of its natural frequency, which is about 10 cycles per sec. This vibration is due to the violent pulsation of the water discharged through the outlet.

Superimposed on the fundamental vibration of 10 cycles per sec., measured at the fixed points *K* and corresponding to the natural frequency of the arched dam, was a harmonic of 50 to 70 cycles per sec., probably caused by the flow breaking away at the bottom of the gate. As might be expected, harmonic vibration ceased when the gate was completely raised so that

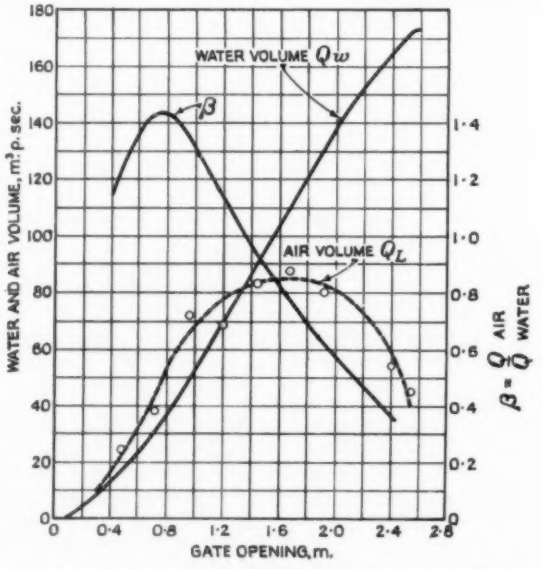


Fig. 32. Measurement of air volume on a 1 : 12 model of a jet-flow gate

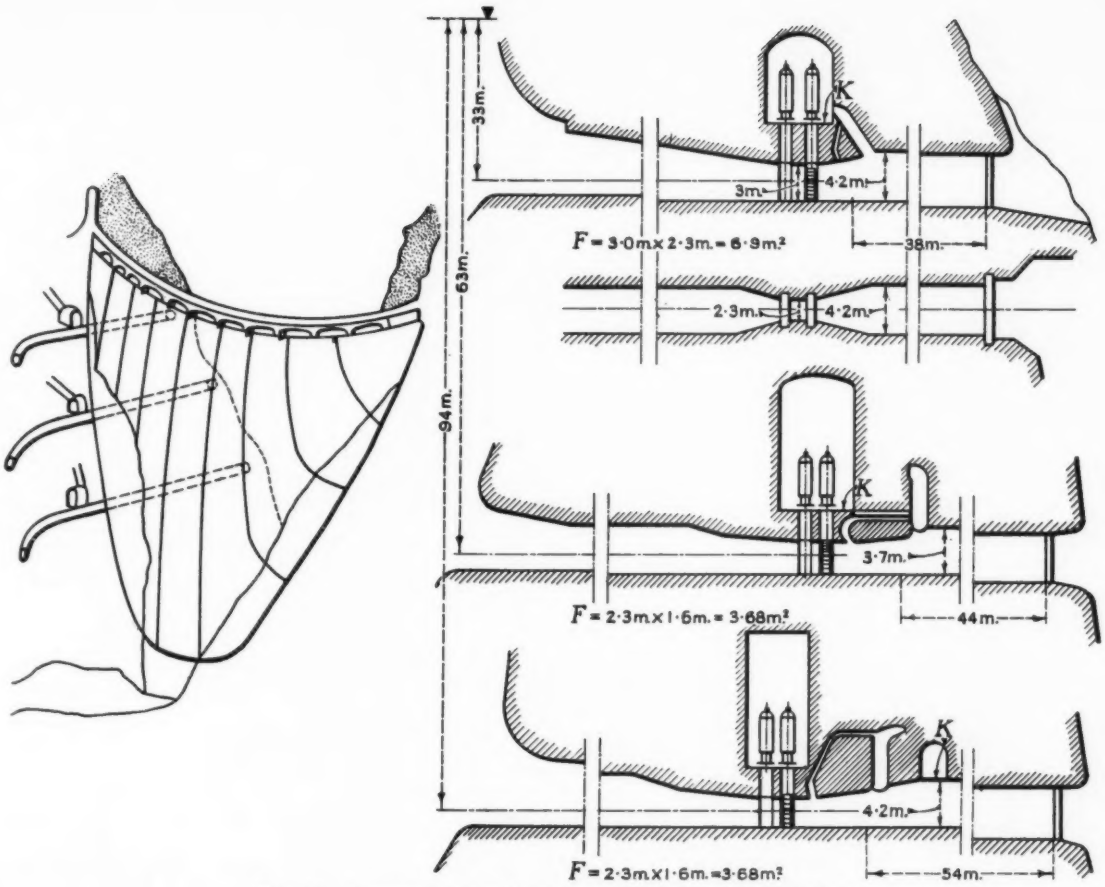


Fig. 33. Arrangement of bottom-outlet gates, Lumiei dam

no eddies could detach themselves from the bottom edge.

The amplitude of fundamental vibration was 3/100 mm. and that of the harmonic about half as much, meaning that acceleration was less than 1 m. per sec.^{2} and safe operation of the gates was not in jeopardy.

When the air inlet was partly blocked in order to determine the effect of air inflow on gate vibration, measurements taken with the gate half-way up showed that gate vibration was not affected as long as 16% of the cross-sectional area was left open. It was of the same order as dam vibration with unobstructed air inlet. Only when the air inflow area was reduced to 8% did the frequency of vibration at the gate cylinder increase (4 to 6 fold) without any change in amplitude. Under these conditions, acceleration, hence mass forces, increase to 40 times their normal value with unobstructed air passage. Another effect of throttling

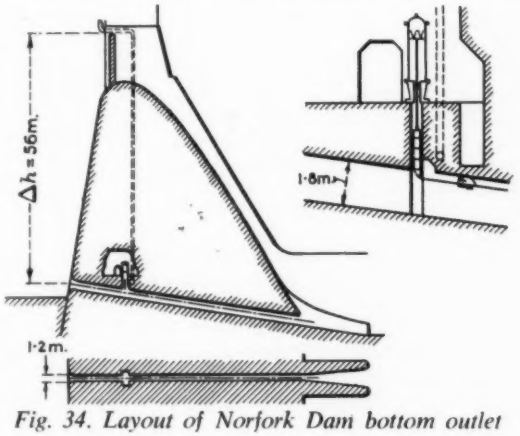


Fig. 34. Layout of Norfork Dam bottom outlet

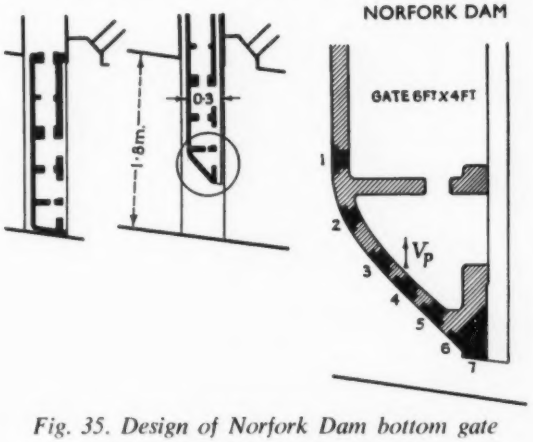


Fig. 35. Design of Norfork Dam bottom gate

is the considerable reduction in pressure below the gate. The rise in frequency and acceleration indicated that further blocking of air inlets would become too risky. The results of measurements taken on the piston rod were similar.

These investigations clearly established the outstanding importance of correct sizing of ventilating facilities, i.e., determination of the appropriate β-value, from the viewpoint of gate vibration.

Excessive frequency, hence acceleration, can be very harmful to the gate. From the above relationship between vacuum and frequency it becomes clear that such detrimental effects can be avoided by maintaining a vacuum of not higher than roughly $-2{\cdot}0$ m. behind the gate and planning the layout of the air inlet accordingly.

American measurements made on the bottom outlet gate of the Norfork Dam (Fig. 34) afford a still

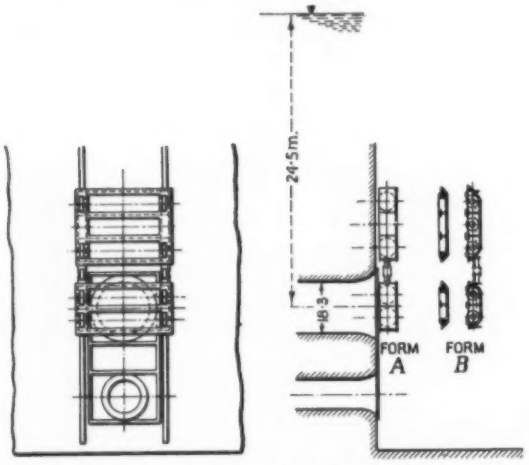


Fig. 36. Twin gate in front of turbine inlet and bottom outlet for use as an emergency closure

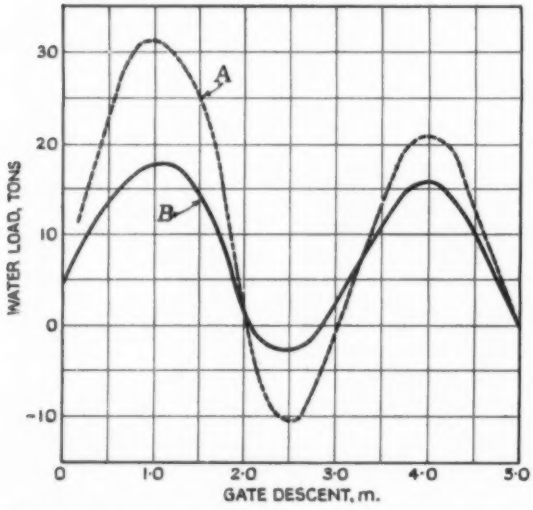


Fig. 37. Water load on emergency gate as a function of gate descent. Zero in the graph corresponds to the top edge of the upper orifice

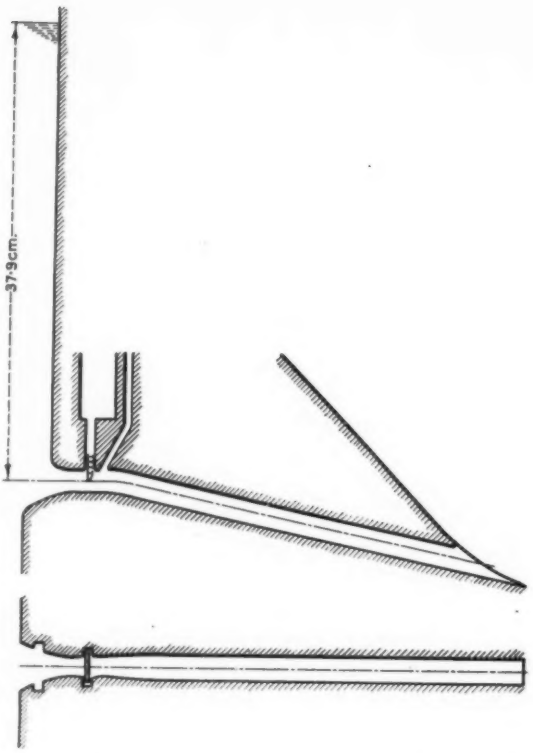


Fig. 38. Water level control gate in gallery; 1 : 20 model tests

better insight into the dynamics of vibration excitation. Installed in the bottom part of the gate were seven inertialess pressure capsules. In addition, a vibrometer was used, and the strain in this part of the gates was determined by strain gauges.

The report on these tests[6] refers to the pressure fluctuation only. For various gate positions the maximum and minimum pressures $P_{max.}$ and $P_{min.}$ were determined at measuring point 1–7. From these results the maximum coefficient of excitation is computed as follows:—

$$C_A = \frac{P_{max.} - P_{min.}}{2 \times \Delta h} \simeq 0{\cdot}075$$

The gate shown at the left in Fig. 35 is the most appropriately designed so far as static considerations are concerned. The webs of the girders in the lower part, where the highest water pressure occurs, are of full height. Measurements on the underside, taken with inertialess pressure capsules, showed that the vacuum was so high that the capsules were very soon destroyed, being unable to withstand the pressures set up by cavitation. Pressures many times the static head were recorded.

The gate with a 45° bevel at the bottom was much better from the viewpoint of hydraulic design. No cavitation was observed at any of the seven points where measurements were taken. However, the presence of a pulsating force was established, acting on the underside of the gate, which initially amounted to $1{\cdot}2$ tons and rose to 4 tons with the gate in its upper position (Table I).

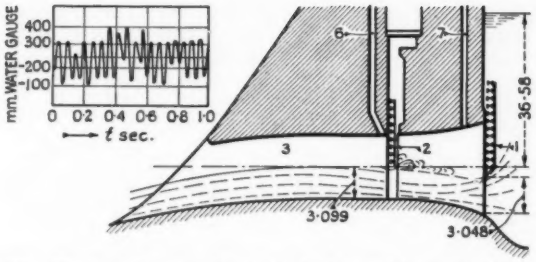


Fig. 39. Level control gate locked in midway position. With the emergency lock gate down and no venting (7) a high vacuum and pulsation were observed in the air space between the two gates—see oscillogram at top left

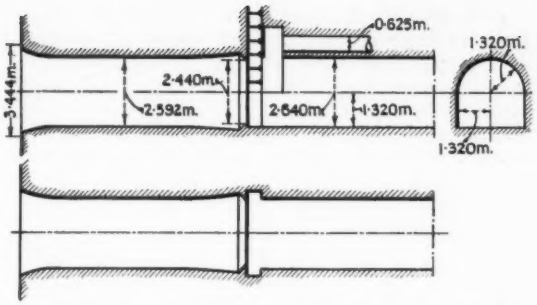


Fig. 40. Section through bottom outlet with a jet-flow gate

TABLE I.

INSTANTANEOUS PRESSURE MEASUREMENTS AT THE BOTTOM OUTLET GATES:

$$C_A = \frac{A}{q \cdot F} \quad \text{or} \quad C_A = \frac{\Delta p}{\Delta h}$$

Designation	C_A	h cps.	Notes
1. Double gate (Fig. 36)	0·04	2·2	1 : 10 model test Vibration is promoted by the gate design "A," the relationship between water load and gate lift (Figs. 36, 37) and the high elasticity of the cable. The vibration tendency was eliminated by an improved gate design "B" and the use of a thicker cable.
2. Flow control gate in tunnel (Fig. 38)	0·02	3	1 : 20 model test
3. Flow control gate in tunnel blocked; emergency gate lowered (Fig. 39)	0·05	18	1 : 20 model test The vibration inducing forces were practically eliminated by the use of a large venting pipe (7). C_A = approx. 0.
4. Jet flow gate (Fig. 40)	0·03		1 : 11 model test Due to inadequate cross-sectional area of the venting pipe the vacuum in the chamber rose to -5 m. and the pulsating pressures were about $=0{\cdot}03$. Installation of larger venting pipes resulted in a decrease in vacuum to about -2 m. and elimination of vibration. C_A = approx. 0.
5. Flow control gate in tunnel (Fig. 28)	0·01	= approx 1	Check measurements made on full scale installation. Pressures were measured with a Bourdon pick-up. Maximum vacuum was $-1{\cdot}8$ m.
6. Norfork dam gate type "B" (Figs. 34, 35)	0·075	20–70	Check measurements made on full scale installation with electrical pressure cells for measuring pressure fluctuations $P_{max.}$, $P_{min.}$ on gate lip. $C_A = \frac{P_{max.} - P_{min.}}{2} \cdot \frac{1}{\Delta h}$ $\Delta h = 56$ m.
7. Garrison dam radial-type gate (Fig. 41)	0·05 to 0·11		1 : 25 model test The maximum instantaneous forces ($C_A = 0{\cdot}11$) were measured at 90% of the total lifting height of the gate. $L_{max.} = 85$ tv., $L_{min.} = 30$ tv. $C_A = \frac{85-30}{2} \cdot \frac{1}{\Delta h F} = 0{\cdot}11$ $F = 4{\cdot}9$ m.^{2} area of girder $\Delta h = 48$ m. water head
8. Kundha dam flow control gate (Fig. 42)	0·03	7 (Model) 1·8 (full scale)	1 : 15 model test

Such dynamic forces assume a particularly important role in gates which are not operated through an oil-hydraulic mechanism or rigid screw hoisting gear, but are suspended from cables of 100 m. length, corresponding to the static head. The elastic elongation of the cables caused by the periodic forces acting can introduce a coupling pattern such that the vibration-inducing forces are amplified. This is why knowledge of the magnitude of these dynamic forces is required for proper planning of the type of hoisting gear to be employed. These instantaneous hydraulic forces were determined on various models and full-scale installations (Table I).

The gate arrangements shown in Fig. 34 to 43 represent various designs, of which Fig. 42 represents the closest to the Norfork Dam gate. The C_A value established in model tests, however, was only 0·02 to 0·05, while the tests conducted at the Norfork Dam give $C_A \sim 0{\cdot}075$. It seems that the design of the knife-edges and recesses, as well as the jet pattern, have an important effect on spray formation in actual practice may obstruct the ventilation ducts, which were open in the model test. It would account for a high vacuum causing reverse flow, pulsation and vibration at the gate while no such condition is observed in the model test. The air inlet, therefore, should be as tight as possible and should be arranged as close as possible to the issuing jet immediately behind the gate. Also, care should be taken to ensure that the venting apertures are not obstructed by deflected jets as a result of secondary flow from recesses or other rounded parts of the structure. The maximum local vacuum occurring with regulating gates should not be over minus 2 m. water column.

It is necessary to check all model test results with a full-scale prototype wherever a new design is employed.

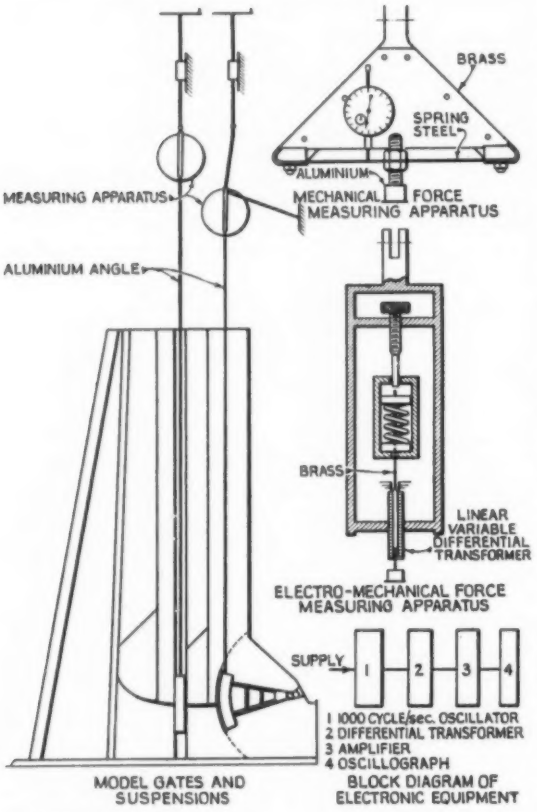


Fig. 41 (above). Model downpull and vibration measuring equipment

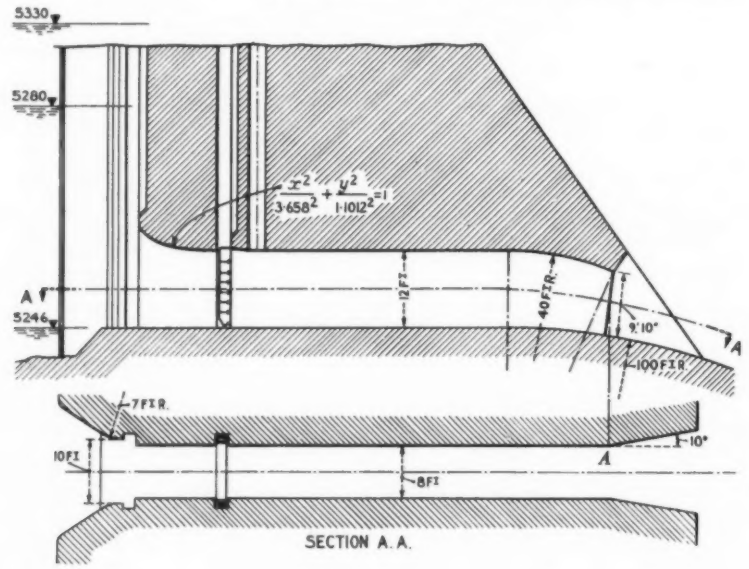


Fig. 42 (right). Flow control gate

BIBLIOGRAPHY

1 K. Petrikat, Die Schwingungsanfachenden Kräfte im Wehrbau (Vibration exciting forces in weir construction), M.A.N. Forschungsheft 1953 (Contains references to further publications).

2 O. Müller, Schwingungs-Untersuchungen an Unterströmten Wehren (Investigating Vibration of Undershot Weirs). Mitteilung der Preussischen Versuchs-Anstalt für Wasserbau und Schiffbau, Berlin 1933.

3 K. Petrikat, Beitrag zur Untersuchung der Schwingungs-Anfachung an überströmten Wehren (A contribution toward the investigation of vibration induction on overshot

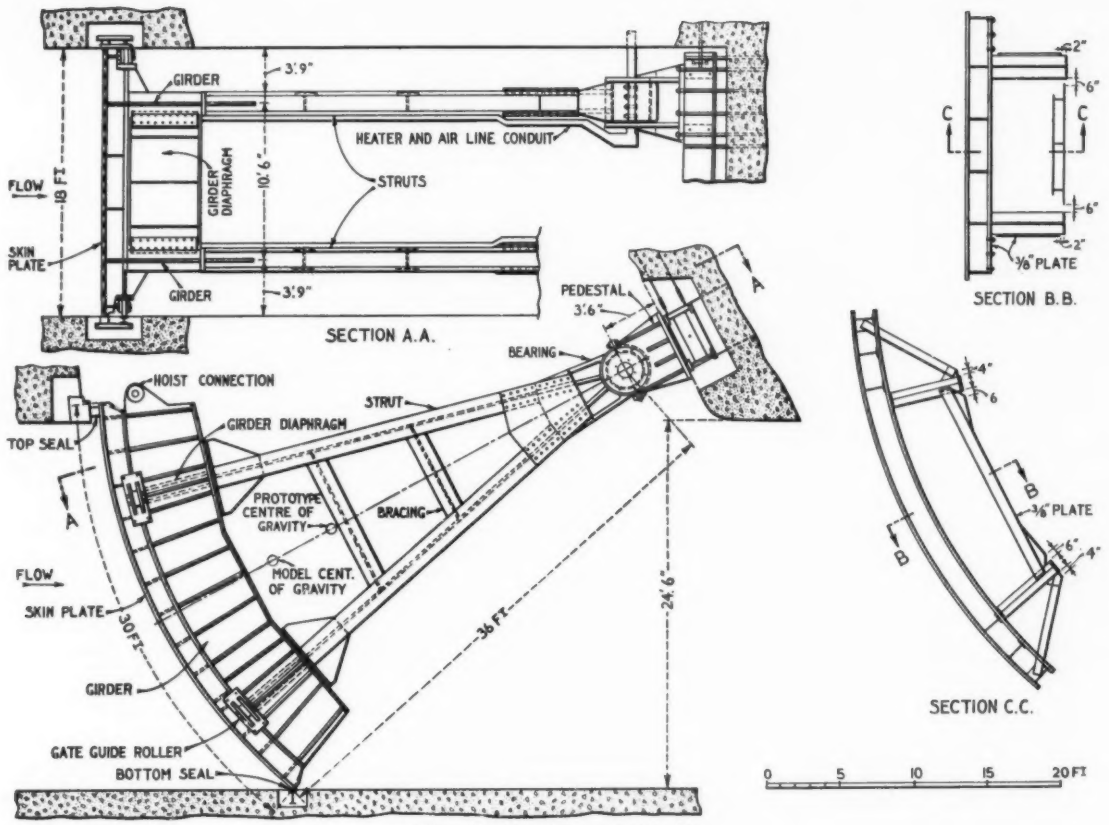


Fig. 43. Service gate details

weirs), Deutsche Wasserwirtschaft 1941.

[4] Proceedings, Minnesota International Hydraulics Convention 1953, Part. IV.

[5] D. Dettmers, Beitrag zur Belüftung von Tiefschützen. (A contribution toward the venting of bottom outlet gates). Mitteilung der Hann. Versuchs-Anstalt für Grundbau und Wasserbau; Franzius Institut der Techn. Hochschule Hannover, No. 4, 1953.

[6] Corps of Engineers, U.S. Army. Slide Gate Tests, Norfork Dam, Techn. Mem. 2–389, July 1954, Waterways Experiment, Station, Vicksburg.

[7] Corps of Engineers, U.S. Army. Outlet Works and Spillway for Garrison Dam, Missouri River, North Dakota. Hydraulic Model Investigation, Technical Memorandum No. 2–431, Waterways Experiment Station, Vicksburg, Mississippi, March 1956.

Water-Power Resources of Canada

The Water Resources Branch, Department of Northern Affairs and National Resources, Canada, has issued its annual review (Bulletin No. 2602) of the potentially available and of the currently developed water powers of Canada. The latest available information regarding water power in each province is summarised and a brief discussion of over-all resources is given under such divisions as provincial distribution, current progress in development, growth of development, general utilisation, and relationship of development to population.

The currently recorded water-power resources of Canada are shown as totalling more than 46 million horse power under conditions of low stream flow and over 66 million horse power at average flow, the latter figure representing a feasible turbine installation of more than 87 million horse power. The total turbine installation at the end of 1957 is given as 19,891,008 h.p., indicating that less than 25 per cent. of available resources has been developed. During 1957, hydro-electric construction continued to accelerate and new capacity to the extent of 1,546,560 h.p. was brought into operation, with good progress made on other new developments; additional projects also were being investigated or planned. Of hydraulic plants, 86 per cent. serve as central electric stations and, in 1957, production reached a new high level.

Copies of this review may be obtained free of charge from the Director, Water Resources Branch, Department of Northern Affairs and National Resources, Ottawa.

World Power Conference. We have been requested to emphasise that, as we stated in our note in our April issue, page 146, applications for the General Programme of the Canadian Sectional Meeting, to be held in Montreal in September, should be addressed to the appropriate National Committees. The Canadian address given in our note applies only to Canadian nationals.

Salzgitter Bunker Train

IN the accompanying illustrations is seen the BZ 35 bunker train manufactured by Salzgitter Maschinen Aktiengesellschaft, Salzgitter-Bad, West Germany, a track-mounted conveyor unit that can be used for the loading and transportation of large quantities of rock and particularly suited to rapid tunnel-driving operations. Loading of material is carried out continuously up to a rate of 107 cu. ft. per min., thus ensuring that the full capacity of the loading machine is employed. Efficiency is increased as the operation of shunting and spotting mine cars at the loader is eliminated.

The BZ 35 is a development of the prototype BZ 15 train and consists of a driving carriage, a number of open-ended bunker wagons coupled together by articulated joints, and a loading carriage. Throughout the length of the train a double-strand scraper chain is installed in the bottom of the wagon elements, the driving drum being sited in the driving carriage and the reversing drum in the loading carriage. The drive is either by a 40 h.p. compressed-air or a 40 kW electric motor, and the chain is equipped with an automatic hydraulic tensioning device.

A loading conveyor, which can be raised or lowered as required and is equipped with a double-strand scraper chain, and a pneumatic pusher are arranged in the loading unit; these ensure that the full cross-sectional area of the hopper wagons, 102·2 sq. ft., is efficiently filled. The loaded rock is then conveyed along to the delivery end of the train, the speed of the scraper chain being varied to match the loading rate.

Unloading of the train may be made into conventional railway units or into dumps and crusher bunkers, no static equipment such as tipplers being required. Discharge at a constant rate is achieved by operating the floor chain conveyor. Unloading a train of 1,236 cu. ft. capacity can, it is claimed, be carried out in 11 to 15 min.

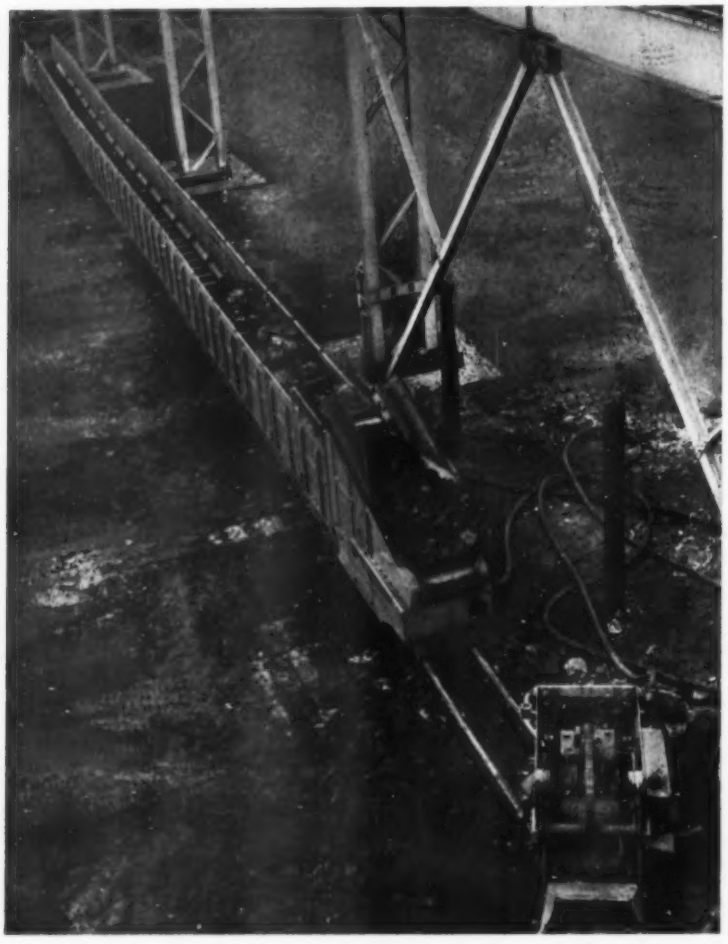


Fig. 1. The loading end of a Salzgitter BZ 35 bunker train

The capacity of the train and the number of bunker wagons employed naturally depend on the prevailing operating conditions, but up to 22 hopper wagons can be used giving the whole train an overall length of 132 ft., and a total loading capacity of 60 tons or 1,250 cu. ft. It is understood that broken rock up to 2 ft. by 3 ft. 4 in. in size can be handled. A mine locomotive of 9 to 12 tons, which can have a travelling speed of 4·3 to 6·2 m.p.h. laden and 6·2 to 8·7 m.p.h. empty, can be utilised for hauling the BZ 35 train. Bends of 66 ft. radius can be negotiated when travelling, although loading and discharging has to be confined to straight track. The standard model is designed for use with a 24 in. gauge track, but in special instances provision can be made for 21¼ in. to 36 in. tracks. The height of the driving carriage and that of the standard bunker wagons is specified at 5 ft. 3 in., while the maximum widths of these items are 3 ft. 11 in. and 3 ft. 5½ in. respectively.

The main application of the bunker train is obviously in rapid tunnel-driving, as its employment can speed up the mucking cycle by handling the broken rock from a complete round of average size in a single trip. According to the manufacturers, this can result in savings of 40 to 50 per cent. for the loading cycle, when compared with the conventional mine-car and shunting practice. In addi-

tion, the BZ 35 unit can be employed for handling supplies such as timber, pipes, and ventilation ducting, and for bringing in and laying crushed ballast for railway track maintenance or drift-floor levelling purposes. A further useful application may be found in the transport of filling material. Where the dimensions of a tunnel permit, and a double track can be installed, two bunker trains can be used with advantage. When this is possible, the filling work can be continuous and 120 tons handled per double haul.

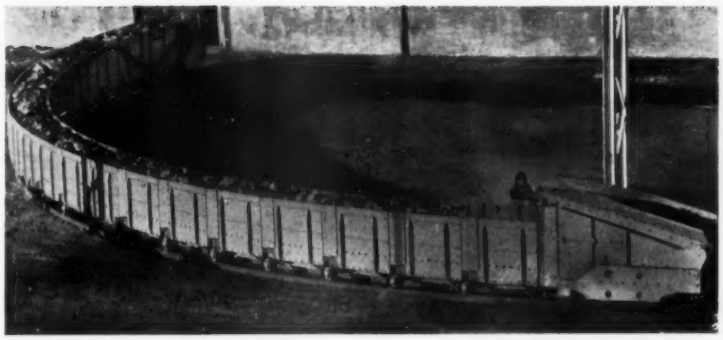


Fig. 2. The BZ 35 bunker train on a curved section of track

Atlas Copco LM Loader

We recently witnessed a demonstration, in a mine heading, of a new rocker-shovel loader, the LM56, recently developed by Atlas Copco for use in tunnels 7–8 ft. wide and with a minimum height of 7 ft. A special version of the loader, the LM56H, is fitted with a higher deck permitting it to fill larger cars, the minimum tunnel height for this version being 7 ft. 10 in.

Practical tests have shown that the net capacity of the loader varies between 53 and 73 cu. yards per hour, depending on the quality of the rock, and it is stated that in relation to its weight and size the LM56 has greater total motor power than any comparable machine of Atlas Copco or other manufacture.

Special care has been devoted to sealing problems to prevent water and dirt from entering the working parts. All bearing covers are provided with O-rings, and the axles and bucket gearbox shaft are protected by oil rings. Releasing the air pressure from the bucket gearbox is effected through an exhaust valve which prevents dust from penetrating the gear bucket if outside overpressure, e.g., when blasting, should occur. Both traction and dumping gearboxes are provided with oil filters, and the machine has a combined air filter, lubricator and shut-off valve. This valve is of the quick-release diaphragm type which immediately exhausts the air from the machine. Service or repair work can then be carried out at once in complete safety.

All movements are controlled by two levers, which can easily be locked to prevent involuntary operation. A fender shrouds the wheels to keep the operator's feet out of danger, and this fender remains in place even should the operator prefer to remove the platform and stand on the floor.

A noticeable operating characteristic of the machine, which impressed us immediately, is its quietness, which has been achieved by fitting the bucket and traction motors and the air controllers with silencers.

For dip loading a winch is mounted on the back of the loader, its air supply being interlocked with that to the traction motor so that the operator controls the machine in the normal manner.

Vinyl Resin Waterstops

On the St. Lawrence Seaway project, long ridged ribbons made of Union Carbide vinyl resins are being sealed into joints between concrete structures to prevent water leakage. Installed when the concrete is poured, these diaphragm-type waterstops for expansion and construction joints are expected by the manufacturers to outlast the structures in which they are used. Sections of a concrete sewer tunnel for the Seaway project at St. Lambert, Quebec, Canada, have these flexible waterstops embedded at the joints between sections (left illustration). Because the waterstops have excellent elongation they can stretch

Emergency in Norway— new Atlas Copco VT4 provides the answer

An outbreak of fire at a hydro-electric plant under construction high in the mountains at Bremanger, Norway, resulted in the total destruction of the compressor installation.

As it was vitally important to maintain an adequate supply of compressed air, an urgent order for two new machines was sent to Atlas Copco, Oslo. Less than three hours later two VT4 compressors were delivered to Oslo's Eastern Railway Station.

The real obstacles were encountered during the last two stages of the journey. As the machines had to be taken by aerial ropeway and finally by helicopter, they were dismantled—a simple operation with the VT4.

Within hours of reaching the site, the VT4 machines were assembled and supplying air to the numerous rock drills and pneumatic tools needed for driving the rock tunnels. This operation proves the value of the remarkable power/weight ratio of the VT4—unrivalled by any other manufacturer.

More power, less weight

Atlas Copco's new VT4 compressor was the ideal machine for this sort of job, because no other portable compressor combines so large a power output with such light weight and small size. The

One of the VT4 machines already assembled

VT4 is the lightest and smallest portable in the 150-160 cfm range, piston or rotary. It gives more cfm per hp than any other, piston or rotary. It is 23-55% lighter per cfm and 26-65% smaller per cfm than all others of its class, piston or rotary. It is 100% air-cooled for use anywhere, any time: thus, on this operation, the fact that the VT4 is independent of other cooling was of great value for operation high in the Norwegian mountains. Air temperature is right for maximum tool efficiency. Outstanding simplicity of design means no specially trained mechanics are needed.

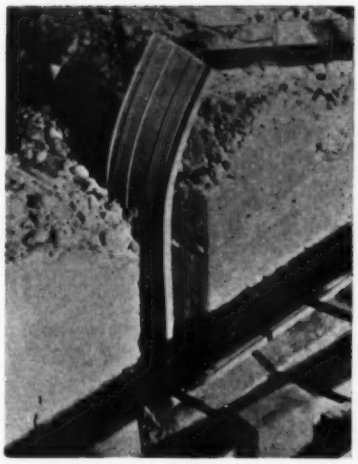
A complete range of compressed air equipment

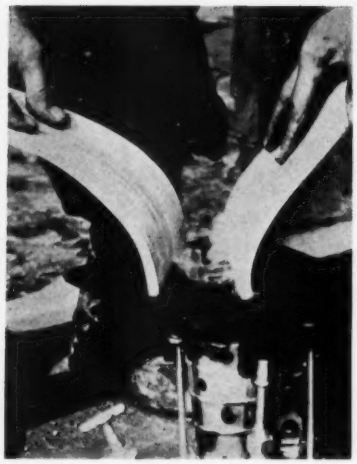
Atlas Copco manufactures portable and stationary compressors, rock-drilling equipment, loaders, pneumatic tools and paint-spraying equipment. Sold and serviced by companies or agents in ninety countries throughout the world.

Atlas Copco PUTS COMPRESSED AIR TO WORK FOR THE WORLD

Contact your local company or agent or write to Atlas Copco AB, Stockholm 1, Sweden.

1958 PARTICIPANT BRUSSELS WORLD FAIR

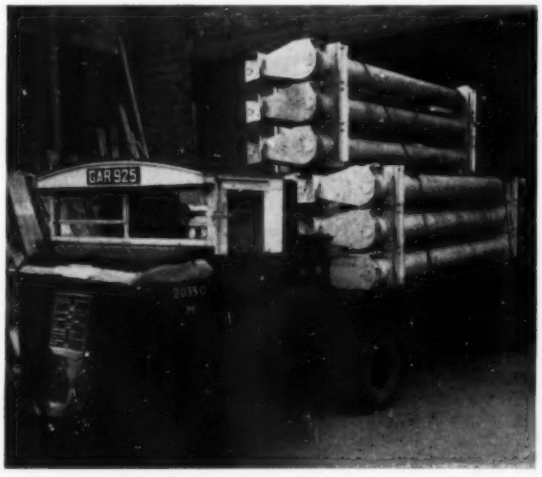




or contract to keep the tunnel watertight as the joints open and close in winter and summer (middle illustration). The vinyl resins were chosen not only for their elasticity and strength but also for their resistance to acids and alkalies. Ridges are formed on both sides of the diaphragm-like ribbon to give the waterstop a better grip on the concrete. The tensile strength is no less than 1,900 lb. per sq. in. (134 kg. per sq. cm.), and the material is stated to have excellent elastomeric properties. It is supplied in 50 ft. (15·2 m.) lengths which are easy to handle when rolled into compact coils. Splicing is simply a matter of heating the ends to be joined and holding them together until they form a bond (right illustration). This saves both time and labour and eliminates welding or vulcanizing equipment. These waterstops are available in a variety of ridge patterns and in widths from 3¼ in. (9·5 cm.) to 9 in. (22·9 cm.).

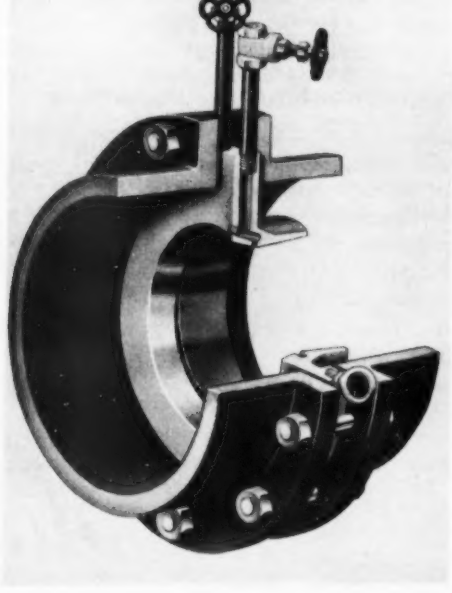
Switchgear for Kariba

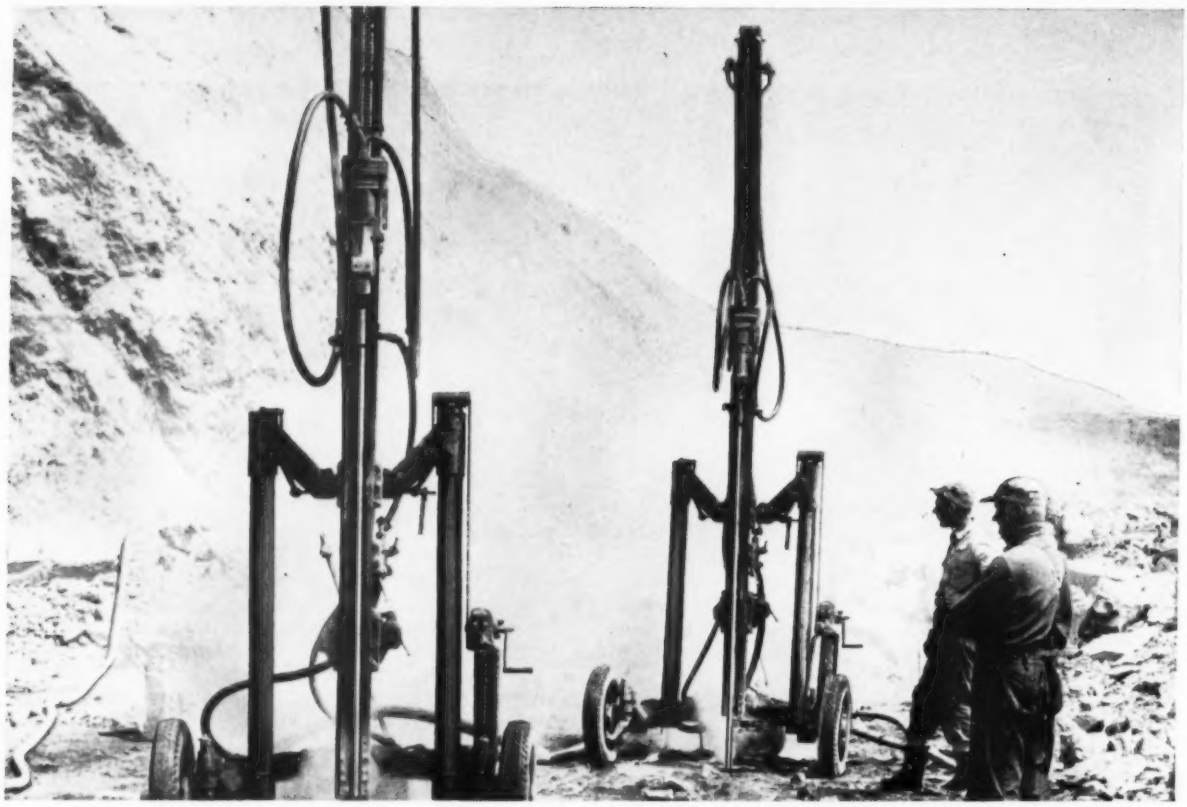
The accompanying photograph shows a consignment of eighteen galvanised steel cases for the 330 kV isolators recently despatched from the British Thomson-Houston Co. Ltd., Willesden Works, to the Federation of Rhodesia and Nyasaland for the Kariba hydro-electric scheme. The BTH contract for the 330 kV switchgear for this scheme includes a total of one hundred and ten isolators which are of the 3-phase, vertical lift pattern with motor operating mechanisms. The Consulting Engineers are Messrs. Merz and McLellan.



The Dall Orifice

George Kent Ltd. announce the introduction of the Dall Orifice, the latest addition to their range of differential-pressure producing devices, designed and developed by the same hydraulic research team that produced the Dall Tube. The Dall Orifice is intermediate both in pressure loss and in cost between the square-edged orifice plate and the Dall Tube. It is thus particularly suitable for use where pressure recovery is of importance but space or first cost pre-





Atlas Copco drills help make maritime history

The £300,000,000 St. Lawrence Seaway project, which will link the Great Lakes with the Atlantic, is now well under way. On many parts of this gigantic project Atlas Copco compressed air equipment has found a wide application. Our illustration shows Atlas Copco BVB 21 Wagon Drills boring holes for channel blasting. Chosen for their reliability and adaptability to a wide range of uses, these drills are proving their worth in the Seaway and on many other major projects.

Atlas Copco BVB 21 Pneumatic Wagon Drills

Weighing only 1,320 lbs, and designed for one-man operation, the Atlas Copco BVB 21 Wagon Drill will readily drill to any depths for practical purposes. Completely adaptable to any angle on uneven ground, it will drill to any angle within a 130° arc. Accommodating eight foot steel changes, it takes all bits from 1⅞" to 4", and has a motor-driven chain feed, with throttles within convenient reach.

The feed motor is reversible to help the extraction of 'stuck' steels without wrenching.

The world's leading drilling combination

Atlas Copco Wagon Drills deserve the world's finest steels. Sandvik Coromant Extension Steels for long hole drilling have many superlative advantages. Cold-rolled from the toughest Swedish steels, they give smoother, faster drilling. Their large-diameter flushing hole—½" in the standard 1¼" equipment—gives a higher rate of advance, better cleaning of the hole, less wear on the bit and less risk of steels sticking. A further advantage is the patented Sandvik rope-thread. This gives a solid, positive connection—and, at the same time, makes screwing and unscrewing an extremely easy operation.

The combination of Atlas Copco drills and Sandvik Coromant Extension Steels, Integral Steels and Detachable Bits is responsible for the drilling of more than 1,000 million feet annually.

World-wide sales and service

The Atlas Copco Group puts compressed air to work for the world. It is the largest group of companies specialising solely in the development and manufacture of compressed air equipment. It embraces Atlas Copco companies or agents manufacturing or selling and servicing Atlas Copco equipment in ninety countries throughout the world. For further details of the equipment featured here, contact your local Atlas Copco Company or Agent, or write to:—Atlas Copco AB, Stockholm 1, Sweden or Atlas Copco (Great Britain) Limited, Beresford Ave., Wembley, Middlesex.

Atlas Copco

1958 PARTICIPANT BRUSSELS WORLD FAIR

Manufacturers of Stationary and Portable Compressors, Rock-Drilling Equipment, Loaders, Pneumatic Tools and Paint-Spraying Equipment

DSS 68

cludes the use of a Dall Tube. A comparison of the pressure losses incurred by various differential-pressure producers shows that on a medium-velocity installation working with a 100 in. w.g. instrument, the pressure loss with a Dall Orifice would be only 19 in. w.g., compared with 60 in. w.g. for an ordinary orifice plate or a flow nozzle. (With a Dall Tube, the loss would be 5 in. w.g.).

The Dall orifice is a self-contained, truncated form of Dall Tube and has a thickness, where it is clamped between the pipe flanges, of only $1\frac{3}{8}$ in. The overall length is 0·3 of the pipe diameter, and the downstream cone simply projects a short way into the downstream pipe.

The design is such that the essential features of the Dall Tube have been retained, while the shorter downstream cone gives the desired compromise between cost, space saving and pressure recovery. The pressure tappings are taken out through the rim, and there are drain or vent holes through the Dall Orifice.

Dall Orifices are at present available for 6 in. to 24 in. pipes, and are normally cast in gunmetal, but high-grade cast iron can be used for some applications on 18 in. and larger sizes.

Abstracts from the World Technical Press

Developments in Tubular Turbines

This article may be regarded as a sequel to Dr. H. C. von Widdern's article, "The Tubular Turbine," published in an earlier issue of *Escher Wyss News* and reproduced practically in full in our January 1955 issue, as it is mainly concerned with design developments that have reached the installation stage since that article was written. After an introduction briefly setting forth the advantages and earlier development of the tubular turbine, culminating in the annular design in which the generator rotor forms a ring surrounding the turbine blades, the next development stage is discussed in which the generator is housed in the draft tube. This arrangement definitely avoids any increase in the overall length of the turbine, but great care is needed to ensure that the presence of such a large foreign body in this sensitive zone does not upset hydraulic performance. Numerous model tests were conducted, and great assistance was derived from aerodynamic tests. This design incorporates a bearing housing on the upstream side of the turbine runner, and the supports for this housing act as guide vanes. In view of the necessarily low speed of these low-head machines, one of the limiting factors of this type of layout is the size of the generator. A successful solution has been the introduction of a planetary speed-increasing gear between the turbine and the generator; this has not only made it possible to employ a generator of reasonable dimensions, but the improvement in generator efficiency has more than compensated for the reduction in mechanical efficiency due to the introduction of the gear. A drawback of such an arrangement is that the generator must normally be designed for a high runaway speed, but this has been overcome by introducing an oil-operated brake which normally locks the outer ring of the planetary gear but releases it in the event of an overspeed, thus freeing the gear. This phase of development was soon superseded by a design in which the generator was installed in the turbine inlet. This presents the advantage that there is no interference with the flow in the draft tube, and in fact it has been possible to develop short draft tubes which avoided the need to increase the overall length of the unit. The need to reach the generator for maintenance led to an investigation of the hydraulic effects of introducing a vertical access shaft, and the important discovery was made that the energy loss was only slightly greater than that due to the normal supporting vanes. This led to the provision of an additional supporting shaft below the generator on which the entire unit can be erected. A comparison between the efficiencies of tubular units of this new design and of equivalent vertical Kaplan machines for the low heads considered shows an improvement in favour of the tubular turbine of 3–6% accompanied by a reduced tendency to cavitation trouble. The remainder of the article is devoted to descriptions of recent installations embodying the features discussed. The 180 h.p. house turbine at the Escher Wyss works at Ravensburg has stationary guide vanes, and the generator is arranged in the draft tube and driven through a planetary gear increasing the speed from 280 to 1,000 r.p.m. The head is 4 m. At Osberghausen a similar type of machine was installed developing 530 h.p. under a head of 7·25 m. and driving an induction generator through a 312/1,015 r.p.m. gear. This was the first installation in which the planetary gear was provided with a brake to release in the event of a runaway. The first Escher Wyss unit in which the generator was arranged upstream of the turbine was in Bürglen, and in this case, for reasons of accessibility, the planetary gear was placed upstream of the generator. This unit develops 610 h.p. at 113 r.p.m. under a head of 3·06 m. A much larger unit was installed in the Reutte power station, developing 1,690 h.p. under a head of 6·07 m. This machine is provided with double regulation by guide vanes and runner blades, similar to a normal Kaplan, and the governor pendulum and runner-blade servomotor are contained within the casing. A summary is given of proposals for harnessing the Mosel river by a series of tubular turbines, based on the use of four 6,000 h.p. units at 5 m. head in each stage. The article concludes with a review of alternative solutions to the mechanical transmission problem, closing means for tubular turbines, and building costs. (A. Pfenninger, *Escher Wyss News*, Vol. 30/1957, No. 2. German, French and English editions available. 14 pp., 25 ff.)

Reversibility of Axial-Flow Machines

A general study is made of the behaviour of axial-flow turbines when running as a pump, or of axial-flow pumps when running as turbines. The tests were carried out on a 300 mm. diameter tubular type model turbine with adjustable runner and guide vanes. Four ranges of tests were effected: (a) machine operating as a normal turbine, (b) as a normal pump, (c) turbine

operating as a pump with flow reversed both on runner and guide vanes, and (d) pump operating as a turbine with reversed flow. The tests also took into account the possibilities of using such reversible machines in tidal schemes and low-head pumped-storage plants. In his conclusions, the author stresses two serious disadvantages of reversible hydraulic machines fitted with blades of conventional form. The first is that a considerable drop in efficiency is occasioned and that the pressure distribution is adverse due to the flow resulting from the sharp trailing edge towards the normal leading edge. The paper ends with a review of the pros and contras of the alternative solution of blades of elliptic section. (R. N. Kar, *Power Engineer*, Simla, Vol. 7, No. 4, October 1957, p. 209, 3 pp.).

Penstocks and Intake, Hirakud Dam

A survey is given in this article of the practices involved in the design and erection of steel penstocks with special reference to those installed at Hirakud. As to diameter, the seven penstock liners embedded in the main dam are the largest of their kind in India and also rank among the largest in the world. The five penstocks of units 1, 2, 5, 6 and 7 are 27 ft. in diameter and are of welded construction throughout, while those of 3 and 4 units are riveted and their diameter decreases from 23 ft. at the upstream end to 22 ft. 2 in. at the scroll case end. Both types of penstock are discussed in relation to pre-heating and stress-relieving practice and hydrostatic tests, and the article concludes with a paragraph on the intake openings. (M. K. Gopaliengar, *Power Engineer*, Simla, Vol. 7, No. 4, October 1957, p. 190, 10 p.p., 7 ff.)

NOTE: The above mentioned journal also contains an Assessment of India's Hydro-electric Resources by M. Hayath and K. L. Vij, p. 200, 5 pp., 1 map.

Protecting Tidal Power Schemes from Corrosion

In the first part of this paper, the author briefly reviews the methods applied heretofore to protect from corrosion metal structures in contact with sea water. Paint coatings, cathodic protection, use of corrosion-resisting metals, etc., are considered. Special types of generating sets intended for tidal plants are also discussed. The second part gives an account of the extensive tests carried out at St. Servan, on the site of the planned St. Malo tidal scheme with corrosion-proof coatings and various steel alloys. Cathodic protection is not included in this paper and will be dealt with at a later date by the team of the French Gas Board, who have been conducting this type of test. (R. Rath and G. Surrel, *Mémoires et Travaux de la Société Hydrotechnique de France*, published as a special issue of *La Houille Blanche*, Vol. 12, No. B., October 1957, p. 651, 15 pp., 12 ff.)

Flow in Porous Media

In this paper the author, proceeding from Southwell's relaxation methods, deals especially with their application to the study of some flows occurring in earthfill dams. The differential equation for plane flow in a heterogeneous and anisotropic medium is transposed in terms of finite differences. The classic formulae relating to a heterogeneous and anisotropic medium are deduced as a particular case. In the investigation of boundary conditions, the free surface is assumed to be made up of straight segments coincident with the squaring lines. Once the definitive potentials have been calculated for the nodes near the free surface, the points of these are determined by interpolation or extrapolation. The method, thus speeded up, is applied to some plane flows. The advantages of this theoretical method over electric analogues are stressed. (G. Matta, Beyrouth, *Mémoires et Travaux de la Société Hydrotechnique de France*, published as a special issue of *La Houille Blanche*, Vol. 12, No. B., October 1957, p. 633, 7 pp., 8 ff.)

Stress-Relieving Steel Penstock on the Job

This article briefly describes the procedure adopted at the Swift hydro-electric project in Washington for relieving stress in the joints of the steel liner which reinforces a power tunnel 1,575 ft. long and 25 ft. in diameter. At the power house, the tunnel branches into three penstocks. This results in two joints which include both a reduction in diameter and a lateral joint, which is reinforced with a heavy ring girder. All the work is welded in the field and it was necessary to stress-relieve the assembly, particularly in the crotch of the joint. Two methods were tried, both involving the feeding of propane gas through insulation to low-pressure burner tips by means of 2 in. diameter manifolds, each about 9 ft. long and having 36 nozzles for the propane. On the first stress-relieving job, the insulation was a high-temperature insulating blanket material which formed a cocoon around the ring girder. Although this worked adequately, there was some difficulty in maintaining a uniform heat distribution. On the second operation, a block-type insulation was substituted for the blanket type. Fuel was supplied from a 9,600 gal. propane tank. Thermocouples located at strategic points checked the shell heat. The steel shell of the liner was hauled to the site in 10 ft. sections, three such sections forming a complete circle. Automatic submerged arc with pressure back-up joined the three sections into a ring.. Then two complete rings were welded together for a 20 ft. length before being placed into the tunnel. Inside the tunnel, manual welding was required. (*Engineering News-Record*, Vol. 160, No. 2, January 9, 1958, p. 40-41, 6 ff.)

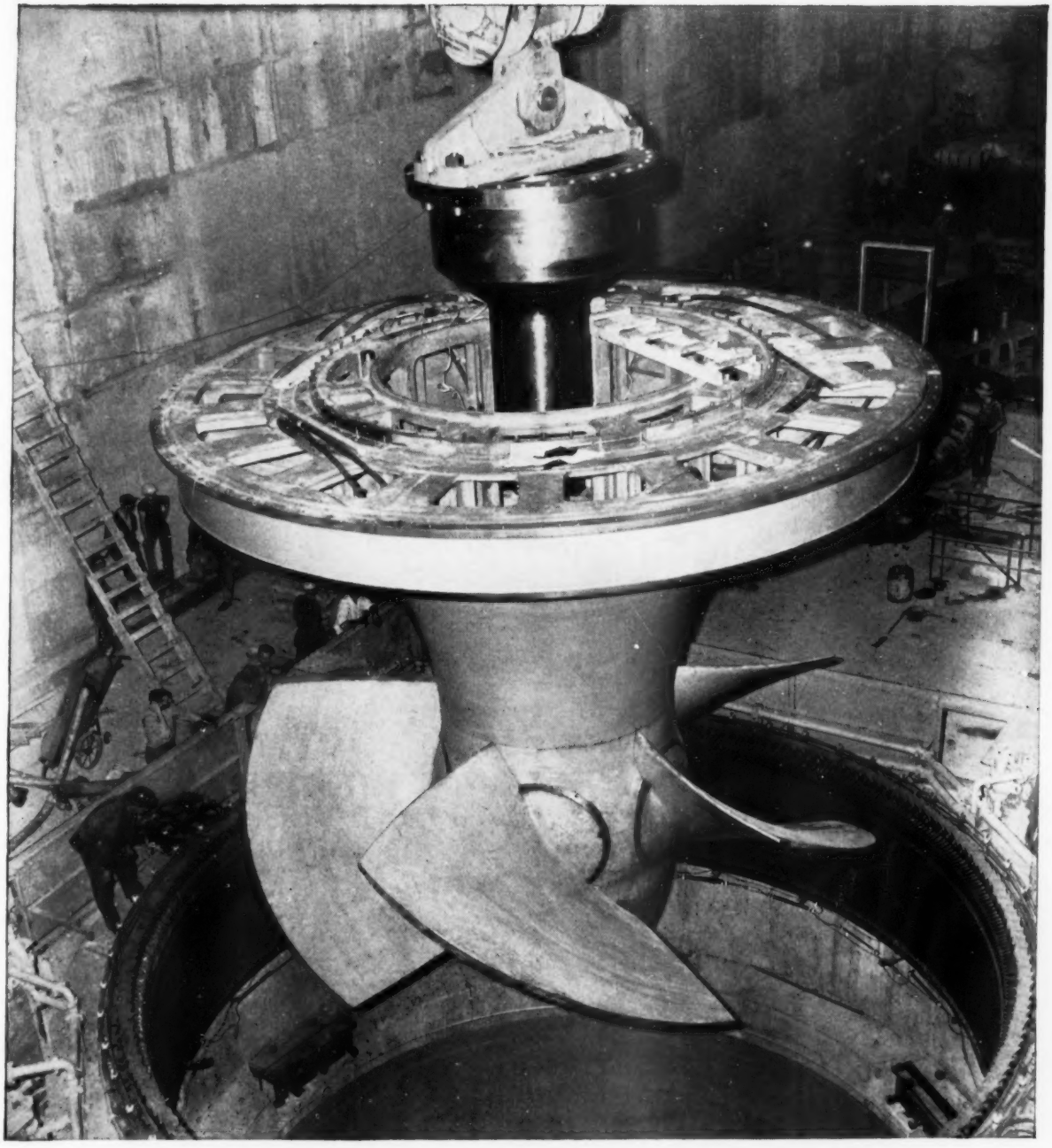
CLASSIFIED ADVERTISEMENTS

Announcements for this column can be accepted up to the 8th of the month for the following month's issue. The charges are fourpence per word with a minimum of 10s. Box No. facilities 2s. 6d. extra. In order to avoid accountancy it would be appreciated if instructions to insert were accompanied with remittance.

Displayed classified advertising for situations vacant, situations wanted, public appointments, are accepted at £2 10s. 0d. per column inch.

Engineering Supplies

BALL AND ROLLER BEARINGS, etc., Wanted! Also surplus goods—especially hand tools—of all descriptions. For Sale: Metal boxes of strong and sturdy gauge and construction with handles, in all sizes. Ask for details.—R. Pordes, 138, New Cavendish Street, London, W.1. MUSeum 5250.

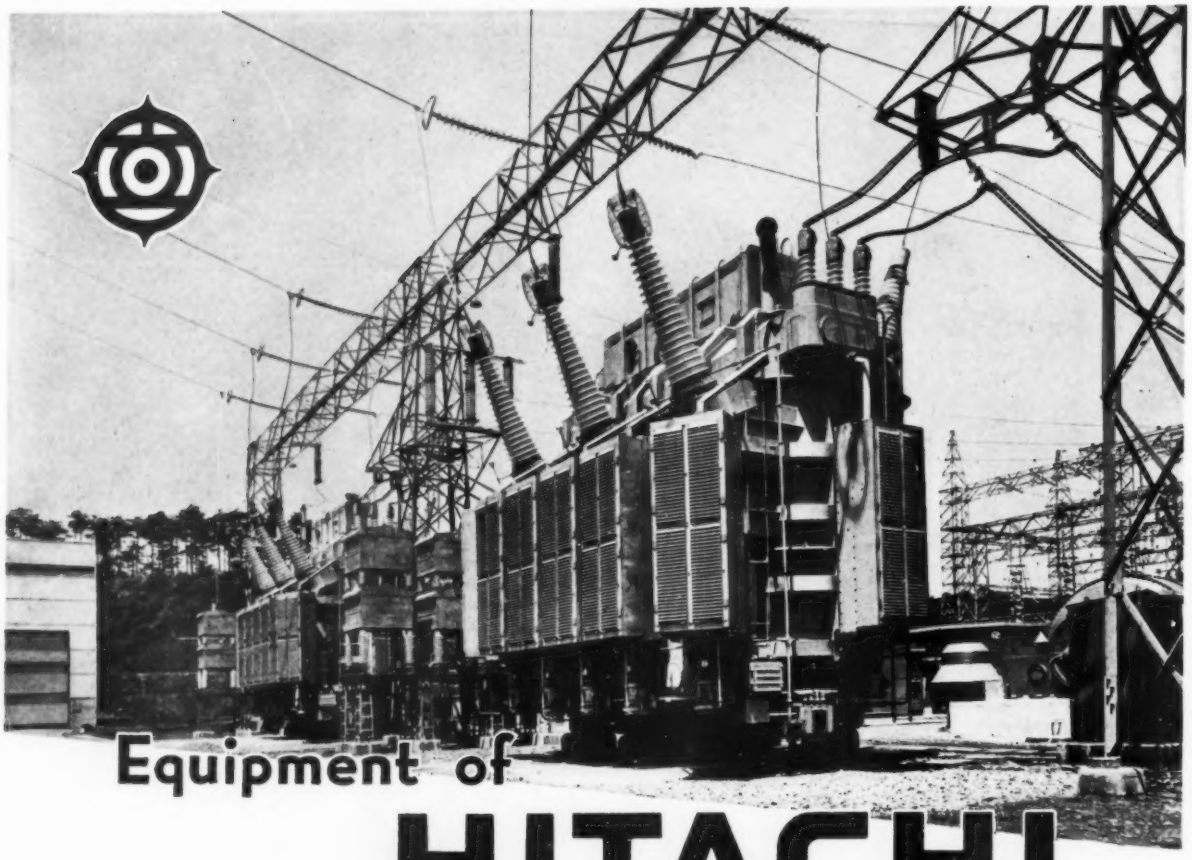


DOMINION KAPLAN TURBINES FOR BEECHWOOD

One of the 45,000 H.P. hydraulic turbine runners being lowered into position at the New Brunswick Electric Power Commission Beechwood power station on the St. John River.

Delegates to the World Power Conference Sectional Meeting, Sept. 1958 in Montreal, are welcome to visit our plant.

DOMINION ENGINEERING
COMPANY LIMITED, Montreal, Canada



Equipment of

HITACHI

for Substation Service

The photo shows Hitachi's 156,000 kVA super high-voltage transformers in service at the Nishi Tokyo Substation of the Electric Power Development Co. These outdoor type transformers are of 3-phase, 3-winding, core type, forced oil and air-cooled system. The high and medium voltage winding of these transformers is provided with a Hitachi patent controsurge winding to increase their series electrostatic capacity and improve impulse voltage characteristics.

MAIN PRODUCTS

Generators, Turbines, Transformers and Other Equipment for Power Plants and Substations.
Locomotives and Other Rolling Stock.
Motors, Cranes, Pumps, Compressors, Refrigerators and Other Industrial Machinery. Printing Presses, Machine Tools.

Household Electric Appliances. Electron Microscopes and Other Precision Scientific Instruments.
Telephones and Switchboards. Electron Tubes, Fluorescent and Incandescent Lamps.
Electric Wires and Cables. Steel and Iron Products.

Cable Address: " HITACHY " TOKYO

Hitachi, Ltd.
Tokyo Japan

Intake Gates

Illustrated is a completely assembled Intake Gate being lowered into position. This is one of twelve built by Canadian Vickers for the Pumped Storage Scheme part of the Sir Adam Beck No. 2 Development of the Hydro Electric Power Commission of Ontario, at Queenstown.

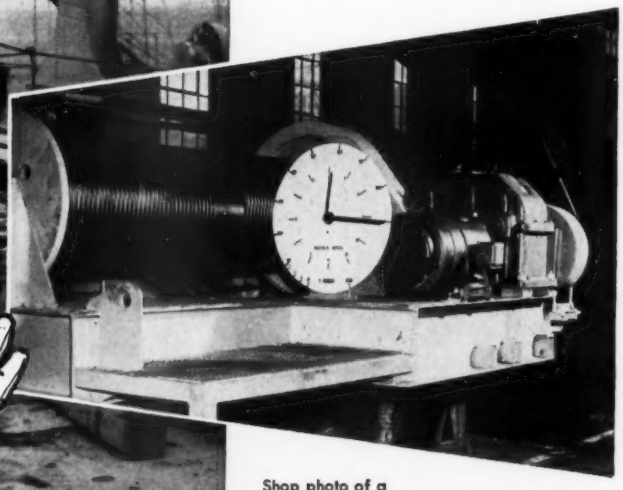
Shop welded in sections and riveted together in the field, these Gates are designed for a clear opening of 16′-8¾″ wide and 34′-9″ high and subjected to a maximum head on the sill of 77′-6″.

Canadian Vickers designs and builds all types of Water-Way and Water-Power equipment. If it is Vickers-built . . . it's right.

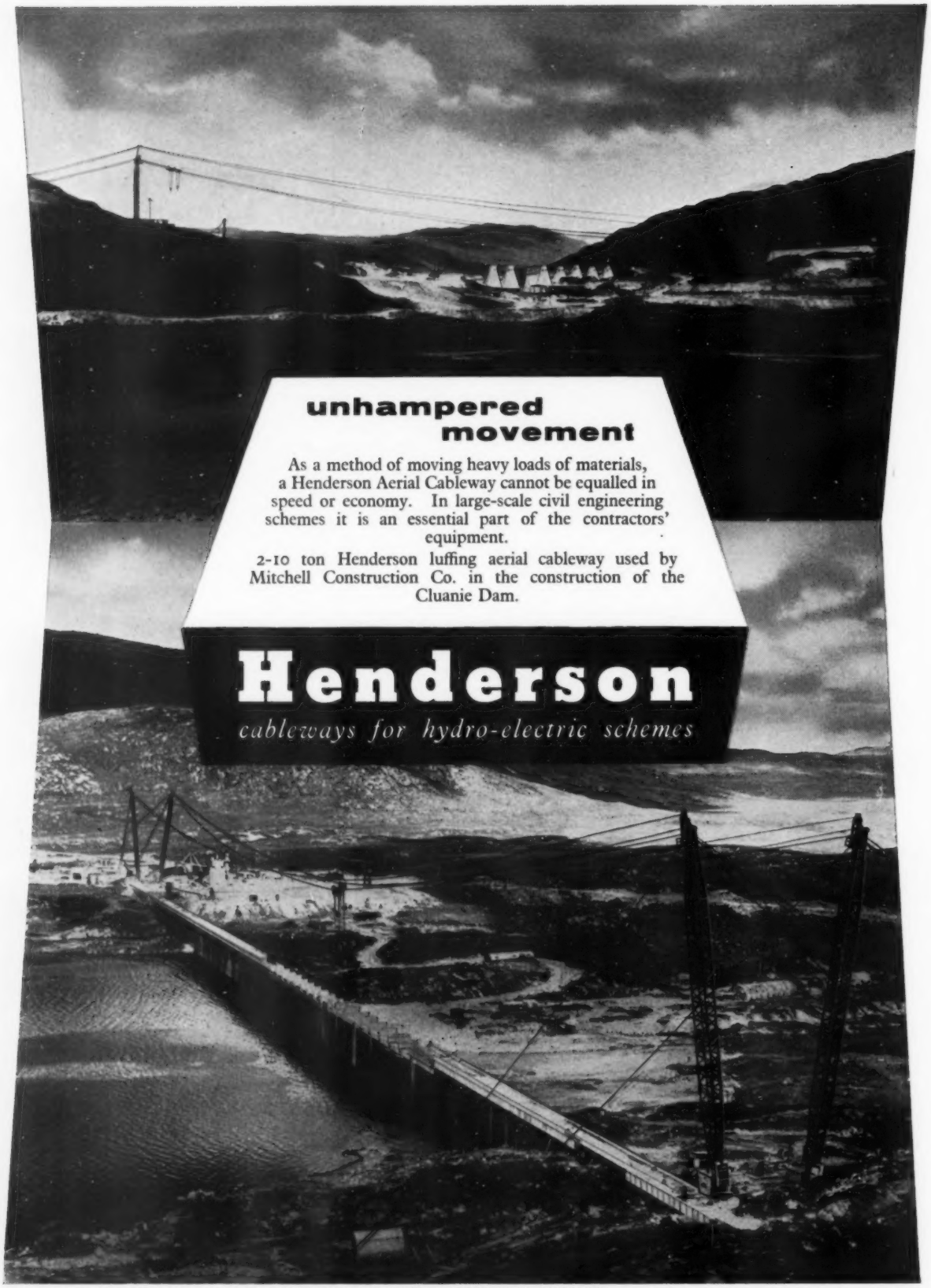
CANADIAN VICKERS LIMITED

MONTREAL TORONTO

CANADIAN MEMBER OF THE VICKERS GROUP



Shop photo of a Vickers-built Hoist.

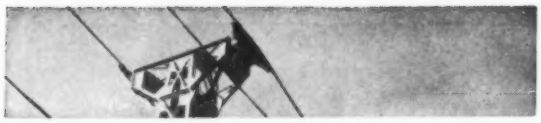

unhampered
movement
As a method of moving heavy loads of materials, a Henderson Aerial Cableway cannot be equalled in speed or economy. In large-scale civil engineering schemes it is an essential part of the contractors' equipment.
2-10 ton Henderson luffing aerial cableway used by Mitchell Construction Co. in the construction of the Cluanie Dam.
Henderson
cableways for hydro-electric schemes

JOHN M HENDERSON AND COMPANY LIMITED KING'S WORKS ABERDEEN SCOTLAND TEL CENTRAL 24262 (3 lines) GRAMS CRANES ABERDEEN
P1099

A range of 13 Oerlikon Minimum Oil Content Circuit Breakers, new Type TOFQ, for 60 kV, 2500 MVA, 1200 A in an open-air station

We are also makers of alternators and transformers for the largest outputs and the most extreme operating conditions, of signalling and control equipment for switchboards, electric traction equipment, Steam turbines, Radial blowers and Compressors for mining and industrial purposes.

Oerlikon Engineering Company • Zurich 50 (Switzerland)



ROPEWAYS AND CABLEWAYS

For nearly 70 years Ceretti & Tanfani have been building literally thousands of miles of ropeways and cableways to carry men and materials in all parts of the world.

This experience is available to you—please consult us.

Ceretti & Tanfani
ROPEWAY CO. LTD.
LONDON

CERETTI & TANFANI ROPEWAY CO. LIMITED.

IMPERIAL HOUSE, DOMINION STREET, LONDON, E.C.2. Telephone: MONarch 7000 (20 lines)

WATER POWER

SUBSCRIPTION ORDER FORM

Beginning with the next issue please post your Journal monthly for one year.

NAME.....

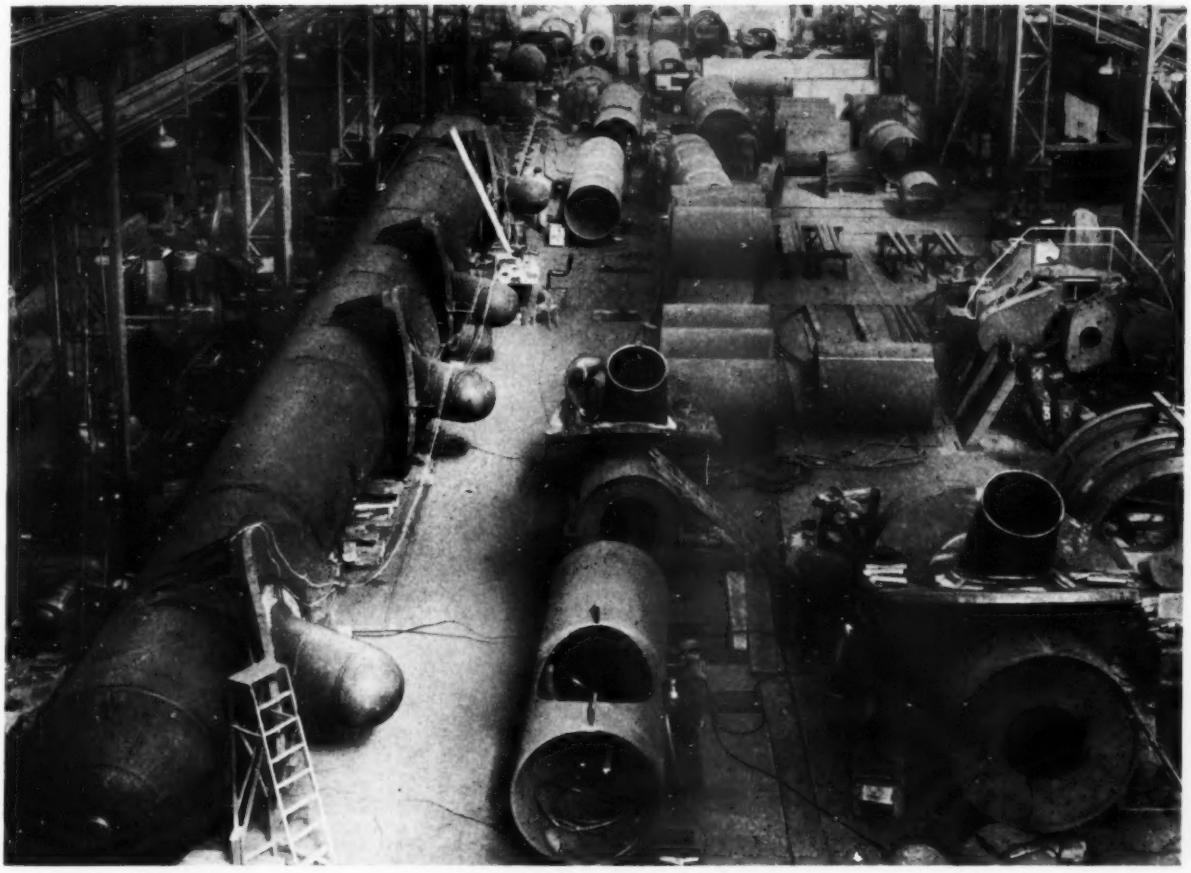
ADDRESS.....

.....

Subscription Rate is 40s. per annum post free

33 TOTHILL STREET, WESTMINSTER, LONDON, S.W.1

Penstocks, pressure shafts linings,
Substation steel structures
Gantry and overhead travelling cranes
Pylons, water gates



Downstream portion of the Grande Dixence Fionnay Power Station distribution pipe during tensometric shop tests. Max. wall thickness 52 mm., service pressure 96 at., test pressure 121 at.

GIOVANOLA

Monthey - Switzerland

VALVES & PENSTOCKS

ELECTRICALLY OPERATED

WITH

HARTLEY "VALECTRIC" HEADSTOCKS

LOCAL OR REMOTE CONTROL

ALL SIZES UP TO 100 SQUARE FT.

CIRCULAR OR RECTANGULAR

ORDERS FROM

CEA and LCC

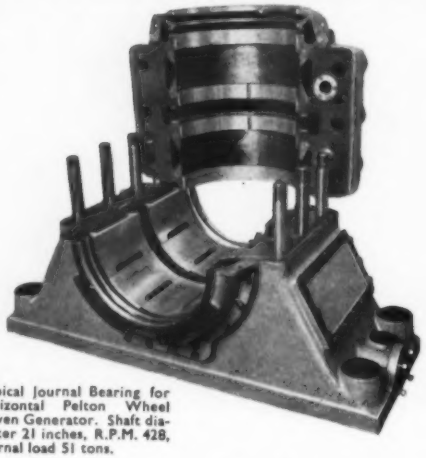
AMONGST OTHERS

HARTLEYS (STOKE ON TRENT) LTD.

ENGINEERS · STOKE ON TRENT

Please write for our pamphlet P5.

12" SLUICEVALVE Operated by a "VALECTRIC" HEADSTOCK



Typical Journal Bearing for horizontal Pelton Wheel driven Generator. Shaft diameter 21 inches, R.P.M. 428, Journal load 51 tons.

MICHELL BEARINGS

The original pivoted pad film lubricated bearings. They carry loads with complete reliability and efficiency with downright simplicity for all Hydro-Electrical installations, and for Marine, Mining, Paper-Making Machinery and other requirements.

MICHELL BEARINGS LTD.

SOUTH BENWELL NEWCASTLE UPON TYNE 5

Telephone 34279 Telegrams: MICHBEARO, NEWCASTLE

THE RAILWAY GAZETTE
A journal of Railway Management, Engineering, Operation, and Railway News. *Weekly 2s. Annually £5 by post.*

DIESEL RAILWAY TRACTION
A monthly review of world-wide developments in diesel-engine design and diesel railway traction. *Monthly 2s. 6d. Annually 35s. by post.*

SHIPBUILDING AND SHIPPING RECORD
A journal of Shipbuilding, Marine Engineering, Docks, Harbours, and Shipping. *Weekly 2s. Annually £5 by post.*

NEW COMMONWEALTH
Describes and illustrates significant developments in production, trade, transportation, and related spheres in all countries of the Commonwealth. *Fortnightly 2s. Annually £3 by post.*

COLLIERY ENGINEERING
A practical journal for Colliery Managers and Engineers, and manufacturers of Colliery Equipment. *Monthly 2s. 6d. Annually £2 by post.*

COKE AND GAS
A technical journal dealing with the scientific and technical problems involved in the production of coke and gas in coke ovens and gasworks. *Monthly 2s. 6d. Annually 35s. by post.*

THE INDUSTRIAL CHEMIST
A journal devoted to the progress of applied Chemistry and Engineering. *Monthly 2s. 6d. Annually £2 by post.*

ARCHITECTURE AND BUILDING
A practical journal devoted to Architecture and Building Practice. *Monthly 2s. 6d. Annually 35s. by post.*

WOOD
A practical journal, authoritatively written, superbly illustrated, dealing with the growth, marketing, and use of wood in all its forms. *Monthly 2s. 6d. Annually 35s. by post.*

FOOD
A journal devoted to the manufacture, packaging, and marketing of processed foodstuffs. *Monthly 2s. 6d. Annually £2 by post*

WATER POWER
A technical journal devoted to the study of all aspects of Hydro-Electric Development. *Monthly 2s. 6d. Annually £2 by post.*

THE RAILWAY MAGAZINE
A popular magazine containing illustrated articles on Railways and Locomotives. *Monthly 2s. 6d. Annually 35s. by post.*

MINE & QUARRY ENGINEERING
Articles of technical nature cover geology, modern methods of prospecting, the winning of ore and stone, the dressing of ore and minerals, and extraction metallurgy. *Monthly 2s. 6d. Annually 35s. by post.*

TOTHILL PRESS LIMITED

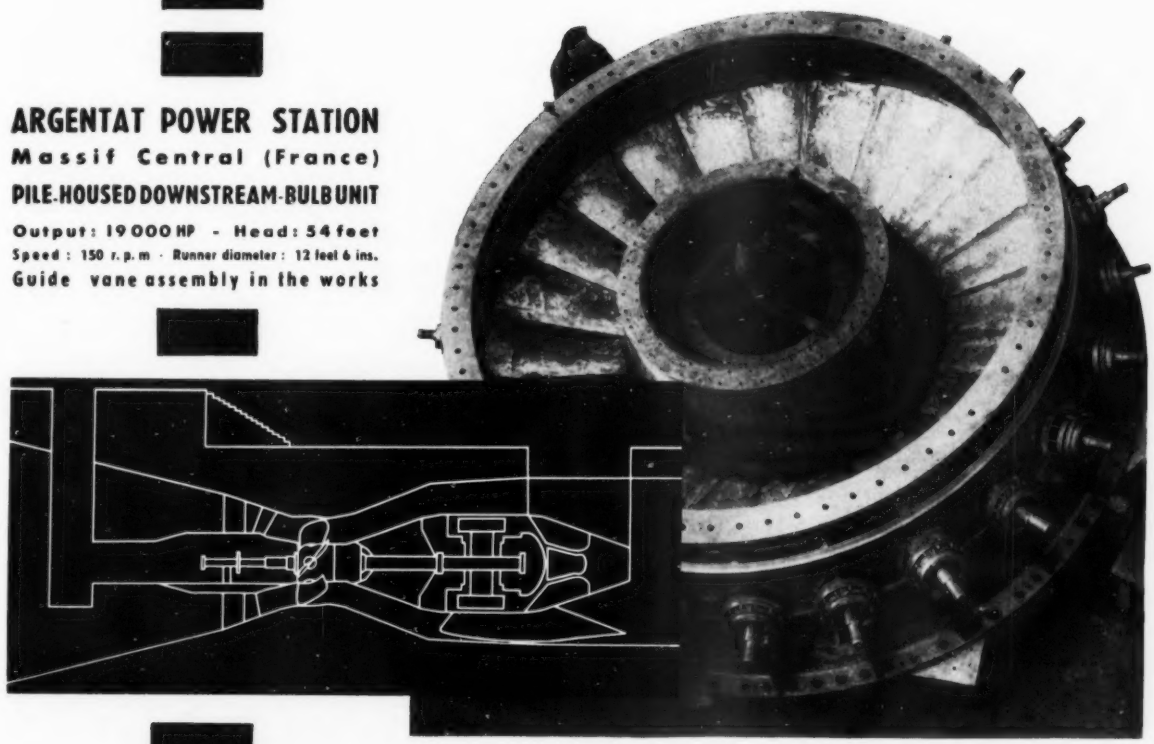
33, Tothill Street, Westminster, London, S.W.1

Axial units

are revolutionizing

the harnessing of tidal energy

ARGENTAT POWER STATION
Massif Central (France)
PILE-HOUSED DOWNSTREAM-BULB UNIT
Output: 19000 HP - Head: 54 feet
Speed: 150 r.p.m - Runner diameter: 12 feet 6 ins.
Guide vane assembly in the works



NEYRPIC

GRENOBLE - Avenue de Beauvert - Téléph 44-55-30
PARIS XVIe - 8, Rue Bellini - Téléph PAS. 51-09

INDEX TO ADVERTISEMENTS

A

A. C. Plant & Hire Co. Ltd., The ... ... —
Acciaieria E Tubificio Di Brescia ... ... —
Allgemeine Elektricitäts-Gesellschaft 29
Allis-Chalmers Manufacturing Co. ... ... —
Allmanna Svenska Electriska Aktiebolaget 35
Aluminium Wire & Cable Co. Ltd. 22
Anderson, Grice, The Company, Ltd. ... ... —
Andritzer Maschinenfabrik ... ...
Ansaldo San Giorgio, S.p.A. ... ... —
Armfield Hydraulic Engineering Co. Ltd. ... ... —
Ateliers de Constructions Electriques de Della ... 19
Atlas Copco AB ... ... 51 & 52

B

Balfour, Beatty & Co. Ltd. ... ... —
Bell, Theodore, & Co. Ltd. ... ... —
Birkett, T. M., Billington & Newton Ltd. ... ... —
Blackie & Son Ltd. ... ... —
Bochumer Verein 33
Bouchayer & Vialett ... ... —
Boving & Co. Ltd. ... ... Front Cover
British Insulated Callender's Cables Ltd. ... ... —
British Pitometer, The Co., Ltd. ... ... —
British Ropeway Engineering Co. Ltd. ... ... —
British Thomson-Houston Co. Ltd. 32
Brown, Boveri & Co. Ltd. 45
Bruce, Peebles & Co. Ltd. 17
Bucyrus-Erie ... ... —
Buss, A.G. 18
Butters Bros. & Co. Ltd. 26

C

Canadian Vickers Ltd. 55
Ceretti & Tanfani Ropeway Co. Ltd. 58
Charmilles Engineering Works Ltd. 34
Compagnia Generale di Elettricita ... ... —
Compagnie Industrielle de Travaux 9
Consolidated Pneumatic Tool Co. Ltd. ... ... —
Craelius Co. Ltd. ... ... —
Crompton Parkinson (Export) Ltd. ... ... —

D

de Roll, Louis, Ironworks Ltd. ... ... —
Dominion Engineering Co. Ltd. 53
Dortmunder Union Bruckenbau, A.G. ... ... —
Drees & Co., G.m.b.H. ... ... —
Dresser Manufacturing Division ... ... —

E

Eimco (Gt. Britain) Ltd. 25
ELIN, A.G. ... ... —
English Electric Co. Ltd. 3
English Steel Corporation Ltd. ... ... —
Escher Wyss Ltd. 7

F

Ferguson Pailin Ltd. ... ... —
Ferranti Ltd. 27
Fischer, Ltd., George 42

G

Galileo Officine di Battaglia Terme ... ... —
General Electric Co. Ltd. ... ... —
Gilbert Gilkes & Gordon Ltd. ... ... —
Giovanola Freres, S.A. 59
Glenfield & Kennedy Ltd. 46

H

Harland Engineering Co. Ltd., The 48
Hartley's (Stoke-on-Trent) Ltd. 60
Henderson, John M. & Co. Ltd. 56
Henley's W. T., Telegraph Works Co. Ltd. ... 28
Hitachi Ltd. 54
Holland & Hannen and Cubitts Ltd. 50
Holman Bros. Ltd. 39
Horseley Bridge & Thos. Piggott Ltd. ... ... —
Huhn, C. ... ... —

I

Ingersoll-Rand Co., Inc. ... ... —
International Engineering Co., Inc. 24

J

Jonneret, S.A. ... ... —

K

Karlstads Mekaniska Werkstad, Akt. 23
Krupp, F. ... ... —
Kuljian Corporation, The ... ... —

L

Leffel, James & Company, The 14
Lepper, K. G. Firma Aug. ... ... —
Le Materiel Electrique, S-W. 9

M

Magrini, S.p.A. 41
Marelli, Ercole & Co., S.p.A. ... ... —
Maschinenfabrik Augsburg-Nurnberg, A.G. 13
Metropolitan-Vickers Electrical Co. Ltd. Outside Back Cover
Michell Bearings Ltd. 60
Mitchell Construction, The Co. 12

N

Neyrpic 61
Newport News Shipbuilding & Dry Dock Co. ... 38
Nuttall Edmund Sons & Co. (London) Ltd. 30
Nydqvist & Holm, A/B ... ... —

O

Oerlikon Engineering Company 57

P

Painter Bros. Ltd. ... ... —
Pellizari, A., & Figli, S.p.A. ... ... —
Pirelli-General Cable Works Ltd. 43

R

Ransomes & Rapier Ltd. ... ... —
Reyrolle, A. & Co. Ltd. ... ... Inside Front Cover
Rip Bits Ltd. ... ... —
Riva, Costruzioni Meccaniche ... ... —
Ruhrstahl, A.G. ... ... —
Ruston Bucyrus Ltd. 6
Ruston & Hornsby Ltd. ... ... —

S

S. A. Ateliers De Secheron 36
SACE Costruzioni Elettromeccaniche ... ... —
Salvi, A. & Co. 47
Salzgitter Maschinen Aktiengesellschaft ... ... —
Scarpa & Magnano 16
Siemens-Schuckertwerke, A.G. ... ... —
Smith, A. O. Corporation, International Div. 10 & 11
Smith, Fredk. & Co. ... ... —
Smith, S. Morgan Company 40
Soc. p. Az. Cementi Armati Ing. Mantelli 5
Societa Nazionale Delle Officine Di Savigliano ... —
Societe des Forges et Ateliers du Creusot 9
Societa Elettro-Morsetterie Volpato 44
Standard Telephones & Cables Ltd. ... ... —
Steatite & Porcelain Products Ltd. 20
Storey, Thos. (Engineers) Ltd. ... ... —
Sulzer Bros. (London) Ltd. ... ... —
Svenska Metallverken, A/B ... ... —

T

Taylor Tunnicliff & Co. Ltd. ... ... —
Technoexport 31
Tees Side Bridge & Engineering Works Ltd. ... ... —
Tokyo Shibaura Electric Co. Ltd. ... ... —
Torno, Giuseppe & Co. 12
Tosi, Franco, S.p.A. 8

V

Vaughan Crane & Co. Ltd. ... ... —
Vevey Engineering Works Ltd. 21
Vereinigte Osterreichische Eisen- und Stahlwerke ... —
Vickers Armstrongs Ltd ... ... —
Voith, J. M., G.m.b.H. 4
Voith, J. M. (St. Pölten) 37

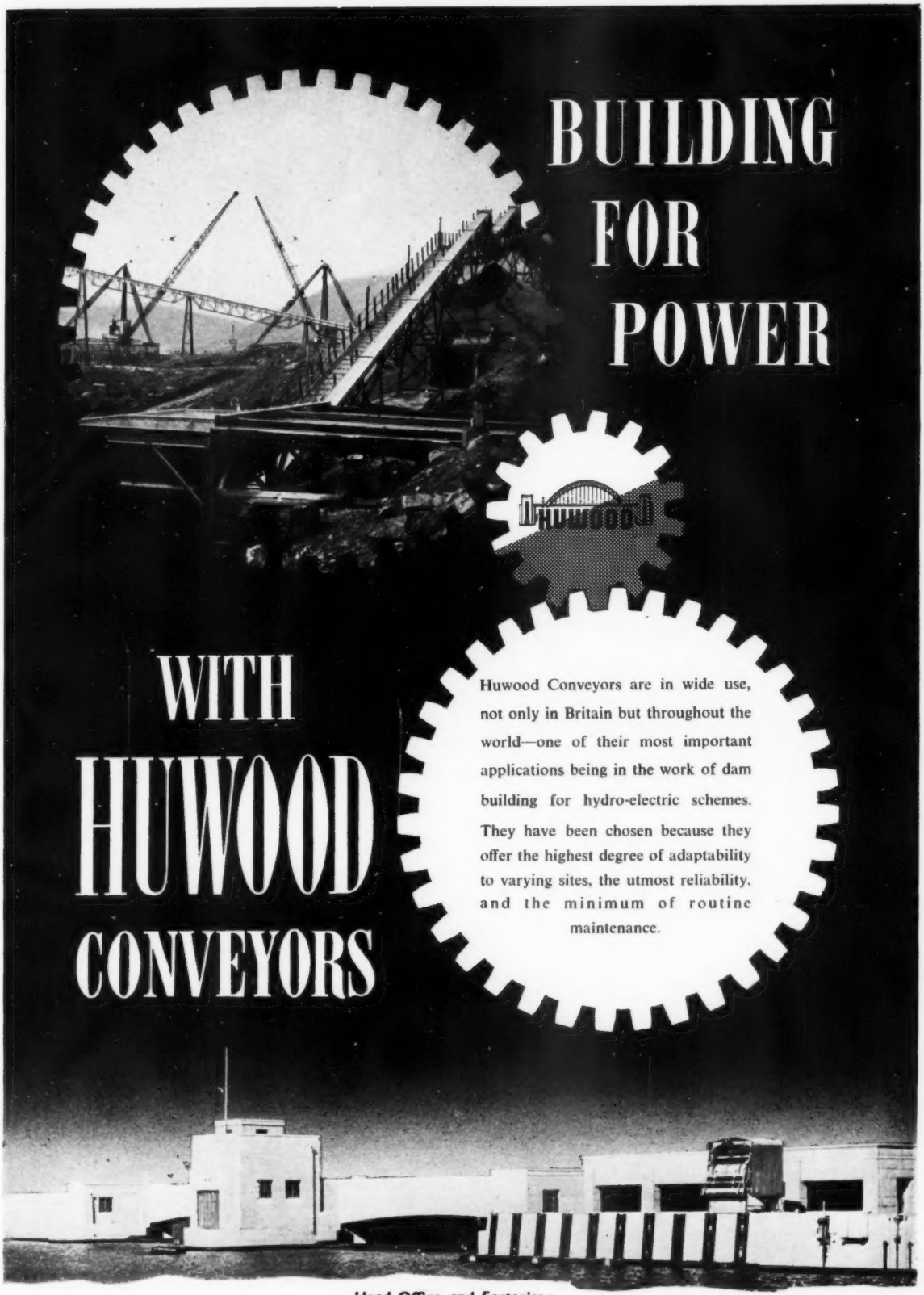
W

Waagner Biro ... ... —
Wailes Dove Bitumastic Ltd. ... ... —
Wild, M. B. & Co. Ltd. ... ... —
Wood, Hugh & Co. Ltd. ... ... Inside Back Cover

Y

Yorkshire Electric Transformer Co. Ltd. ... ... —

LONDON: Published by TOTHILL PRESS LIMITED, Proprietors of WATER POWER, at 33 Tothill Street, Westminster, S.W.1.. and Printed by W. & H. SMITH LTD., Evesham, Worcestershire. *May, 1958*


BUILDING
FOR
POWER
WITH
HUWOOD
CONVEYORS
Huwood Conveyors are in wide use, not only in Britain but throughout the world—one of their most important applications being in the work of dam building for hydro-electric schemes. They have been chosen because they offer the highest degree of adaptability to varying sites, the utmost reliability, and the minimum of routine maintenance.

Head Office and Factories:

Ref. No. Ind/120c/131

HUGH WOOD & CO LTD · GATESHEAD-ON-TYNE 11

INDUSTRIAL & EXPORT OFFICE: ROYAL LONDON HOUSE, FINSBURY SQUARE, LONDON, E.C.2

Wide waters . . . . .

The Kariba Gorge

The upstream entrance to the Kariba Gorge, seen from a promontory at the confluence of the Sanyati and Zambesi Rivers.

THE wide waters of the mighty Zambesi will soon be harnessed to provide power for the development of the vast territory of Central Africa. A dam now being constructed at Kariba will form the largest man-made lake in the world by impounding the waters of the river to provide a controlled flow to the hydro-electric machinery in two power stations.

Metropolitan-Vickers are proud of the leading part they are playing in this development. They are building five 100 MW vertical-type water-turbine-driven generators for the first Kariba Gorge hydro-electric power station of the Federal Powef Board of Rhodesia and Nyasaland. These generators will, when installed, be amongst the largest in the world, having an overall diameter of about 40 ft. and weighing approximately 720 tons each.

This company has unrivalled research facilities and manufacturing resources, and is ready to place at your service its technical competence and experience in heavy electrical engineering matters.

METROPOLITAN-VICKERS

ELECTRICAL CO LTD · TRAFFORD PARK · MANCHESTER 17

An A.E.I. Company

A/C605